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Entering the Seventh Decade of Electric Power

Some Highlights in the History of Electrical Development

By Charles E. Neil
The North American Company

Early Electric Systems—Service Areas—Competition
Power Plant Developments
Developments in Electrical Transmission
Early Price History of the Electric Light
Motors and Diversified Electric Service

Early Troubles of the Power Engineer

A letter of the late
Alex Dow
Chairman of the Board
The Detroit Edison Company

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"I made up my mind that the problem of the subdivision of the electric current could be solved and made commercial."—Thomas A. Edison.

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ON September 4, 1942, the electric light and power industry reached its sixtieth birthday. It now enters upon its seventh decade, one which may prove to be its most important, for a burden is upon it as great as any it has ever faced.

In the early years of the industry, it was a lighting business. At the turn of the century it began to make strides in the supplying of factories with electric motor power. Today its service in lighting the nation is without a counterpart anywhere in the world, but electric power is the emergency all-important factor—power which is being used in huge quantities to forge and process the machines of war.

Tremendous advances have been made in the development and supplying of factory motor power since World War I. In 1914, at the beginning of that conflict, the factories of this country had 3,885,000 horsepower of motors driven by purchased electric energy. At the beginning of World War II, in 1939, the motors on purchased energy had increased to 29,888,000 horsepower—an increase of 670 per cent in the 25 years! Factories in 1914 also had 18,406,000 horsepower of prime movers of their own, to run machinery and motors. In the 25 years to 1939 this figure had increased to 21,236,000 horsepower—or an increase of 15 per cent.

While the proportion of prime movers within the factories dropped from 82.57 per cent in 1914 to 41.54 per cent in 1919, the proportion of electric motors driven by central station energy increased from 17.43 per cent to 58.46 per cent.

The average factory worker in 1914 had an aggregate of 3.20 horsepower at his command, of which 0.56 horsepower was in motors driven by purchased energy. Today each worker has an average of 6.50 horsepower to use, of which 3.80 horsepower is motor power run on purchased energy. The average per-worker purchased energy horsepower is greater today than the total factory horsepower per worker in 1914.

Dr. Karl Compton, in referring to the mechanization of the United States has stated that the engineering advances have made available here 6 billion man-power—"equivalent to 50 slaves for each man, woman and child."

Growth of the Electric Industry

The electric light and power industry has been continuously "among the fastest growing of all forms of enterprise," the Brookings Institution has noted. Measured by production of its energy it truly has demonstrated a remarkable growth, not only from its earliest days up to 1929, but the increase since that year has been extraordinary.

It is extremely doubtful if any industry can show a record of year-to-year *continuous* growth equal to that of the electric light and power industry. The long-time trend clearly shows that the growth by decades has been ever upward. While complete industry figures of electric production do not exist for the early decades, there are available the annual growth figures of some of the central stations from their beginnings in the '80s and '90s. In each of the individual central station statistical growth trends that have been observed, not one showed a decline in any year of the first three or four decades—not even in the depression years, such as 1893 and 1907-8. The original Edison central station and its successor system in New York City recorded a gain in load or production in every year from 1882 to the year 1932, which was the first and only year to show a temporary decline in kilowatt-hour output!

It was not until 1921 that power production for the whole country, as measured by kilowatt-hours, showed a temporary drop. Based on the records of a number of companies, it is probable that this was the first year from 1882 to show a decrease in output. The trend of annual increase in production was resumed the next year, 1922, and has continued except for the 1930-1932 period of the recent depression. Since

TABLE I

Year	*Population Millions*	*Electric Production in Billion Kilowatt-hours*	*Kilowatt-hours per capita*	*Per Cent Increase in Per capita*
1902	79.4	4.8	60	...
1907	87.5	10.6	121	102%
1912	95.1	17.9	188	55
1917	102.2	33.2	325	73
1922	109.9	43.3	394	21
1927	118.2	74.0	626	59
1932	124.6	78.0	626	0
1937	129.0	115.7	897	43
1942	132.6	188.0 (Est.)	1,417	58

then the growth has been rapid. The 1942 output exceeding that of 1929 by 96 per cent, having gone from 96 billion kwhr in 1929 to an estimated 188 million kwhr in 1942.

The production of energy in kilowatt-hours in the United States from the year of the first official census of the electric industry, 1902, to the present year, is given in Table I. The figures include the total output of energy for public use, including energy generated by electric railways, government plants, etc. Production is also shown on a per capita basis.

Early Electric Systems—Service Areas—Competition

Many lighting "systems" preceded the Edison central station system, and many came after its creation. In Great Britain the first lighting system was registered May 31, 1875, under Gramme patents. In 1878 the British Electric Light Company was formed, as sole licensee for the Gramme machines. The record of the early registered companies shows that most of them "wound up" and died; or "nothing paid up"; or "showed a loss." For example, the Brush Electric Light and Power Company of Scotland, registered in 1882, to handle Brush-Lane-Fox patents, "wound up voluntarily" in October 1883. Among the various "systems" were included: Gramme, C. F. Brush, Jablochkoff, Siemens, Swan, Weston-Maxim, Laing, Pilsen, Faure, Fyfe, Gulcher, Chartemps, Joel, Gatehouse, Fitzgerald, Duplex, Sun, etc.

In this country at the same time there were fifty or more separate lighting "systems," mostly for arc lighting. Today only one system survives—the Edison system, all the other systems having "wound up" many years ago as observed by T. C. Martin, "For such a complete disappearance as that it is hard to find a parallel in the arts and mechanics." Two of the more important early lighting systems which made valuable contributions to electrical development were the Brush and Thompson-Houston systems. The manufacturing plant of the latter became the nucleus of the present General Electric Company.

The Brush System

Following the first public demonstration of the Brush arc lamp at Monumental Park, Cleveland, on April 29, 1879, the inventor and organizer Charles F. Brush initiated his first arc lighting central station as a commercial venture in San Francisco. The California Electric Light Company was organized June 30, 1879, to operate the system and actual service began in September, 1879, from the plant which was located at Fourth and Market Streets. The Brush Electric Light & Power Company of New York was organized September 24, 1880, and built a generating station at 133 West 25th Street. Arc service began December 20, 1880, with lights on Broadway from 14th to 25th Streets, and was later extended to 34th Street. By 1881 there were Brush arc stations in Cleveland, Albany, Baltimore, Philadelphia, Boston, Cincinnati, Buffalo, Rochester and other cities.

The T-H System

The Lynn Electric Lighting Company of Lynn, Mass., was the first to use the Thomson-Houston system. The company was formed in 1882 and by 1883 had 90 arc lights in use. Many local companies purchased their arc equipment from the Thomson-Houston Company, and by the end of 1883 Kansas City had installed 210 arc lights of this type. Other T-H installations were: Boston, 200; Hartford, 100; Portland, Me., 75; Quincy, Ill., 45; Des Moines, Iowa, 25; etc.

The Edison System

The breadth of conception of Edison in planning in advance for every branch of the electric central station is one of the most remarkable aspects of the development of the electrical industry. When he first started to work on the problem he could see in his mind the many things he would have to invent and develop on a commercial scale to make such a central station successful.

Edison began by studying every angle of the gas business, with the objective of effecting "exact imitation of all done by gas, so as to replace lighting by gas, by lighting by electricity. . . . It doesn't matter if electricity is used for lighting or for power. Small motors can be used day and night. . . . Generally poorest district for light, best for power, thus evening up the whole city—note the effect of this on investment."

A complete system of electric distribution had to be evolved. Means had to be found to maintain even voltage. Dynamos had to be built more efficient and larger than any then made. ". . . I made up my mind," he wrote, "that I wanted to sell all the electricity I made and not waste half in the machine, so I made my internal resistance small and got 90 per cent of salable electricity." He had to invent and perfect many other devices—to prevent excessive currents—proper switching gear, lamp holders, etc.

The first commercial installation of the Edison incandescent lamp and dynamo system was that made on the steamship "Columbia," which was owned by the Oregon Railroad & Navigation Company, and started on its trip around Cape Horn to San Francisco on May 2, 1880. The famous Pearl Street Station, the first central generating plant and its component distribution system, began operation in New York sixty years ago on September 4, 1882.*

On July 4, 1883, in Sunbury, Pa., the Edison Electric Illuminating Company of that city, first began electric incandescent service with the famous Edison three-wire system, which saved 62½ per cent in the cost of copper conductors. Its successful operation here made it universally adopted in all other Edison stations thereafter. The line in Sunbury was overhead, but shortly thereafter a three-wire system was installed in Brockton, Mass., with underground distribution.

Service Area of Early Edison Plants

The Pearl Street plant in New York served an area about a mile square, the northern-most point reached being Park Row. For some years after the service area of electric plants was limited, and supplied only the central parts of the cities.

In 1904, the late Alex Dow gave some figures of area limits of Edison central stations in the large cities, in which the greater part of the lighting business of the country was then centered. The following table shows some of the cities as to area served by Edison distribution systems:

	In Square Miles	
	Total Area	*Area Served*
New York (Manhattan)	22	15½
Chicago	190	12
Philadelphia	130	3
St. Louis	63	7½
Boston	43	4
Cleveland	33	1½
Detroit	29	3
Buffalo	51	5

It was shortly after this time that the rapid spread of service to the residential

* The N.E.L.A. Bulletin for September, 1922, carries an extensive account of this station by the author.

districts began, until service became available in all parts of both large and small cities.

In the first decades of the electric industry electricity in the home was a luxury and it appeared in few homes for this reason. Complete service was sold by the central stations, and the cost of wiring existing homes, installing chandeliers, lamps, meters, etc., together with the cost of the current came to quite a sum. The first houses to be lighted by electricity were those of E. H. Johnson in Greenwich, Conn., and Senator D. M. Sabin, in Stillwater, Minn., in the early '80s. The first homes to be lighted by an incandescent central station were those of H. J. Rogers, and H. D. Smith and A. L. Smith in Appleton, Wisconsin, in September, 1882. In 1883, in Roselle, N. J., the Edison lamps were placed in some 50 dwellings.

Competition in Various Forms

The Edison incandescent lighting central station was planned as a competitor of the gas lighting business and the electric arc lighting business. The first charges made for incandescent lighting were based on contemporaneous equivalent gas rates. The electric railways were a product of the 1880s and they also became a competitor in the lighting business to a limited extent—by selling a portion of their electric energy for lighting purposes.

The gas industry was 66 years old when Edison developed his electric central station in 1882. Some of the gas companies saw operating advantages and economies possible in the combination of electric and gas systems, which prompted them to install electric systems. In 1907 there were 329 out of the 4,714 electric central stations which were associated with gas enterprises.

Not only central stations, both arc and incandescent, began to spread over the country, but in addition thousands of smaller "isolated plants" were installed by individual customers, including many Edison isolated plants. In 1902 when there were some 3,600 electric central stations there were also about 50,000 isolated plants in the United States, having facilities about equal to the capacity of the central stations. In Greater New York in 1899 there were 1,250,000 16-cp lamp equivalent capacity in the central stations and 800,000 in the isolated plants. In Chicago the capacity of the isolated plants at that time exceeded that of the central stations.

The arc and the incandescent branches of electric lighting grew up quite independently for several years after their inception. There was intense commercial rivalry between companies of the two types. However, some arc companies soon began to operate also with incandescent lamps and by 1897 many of the stations were selling both arc and incandescent lighting.

In New York state the proportion of revenues derived from lighting and other services changed from 1890 to 1907 as shown in the following table:

Percent of Income—New York State

	1890	*1902*	*1907*
Arc lighting	54.43%	29.34%	....
Incandescent lighting	38.00	47.32	....
Total Lighting ..	92.43	76.66	69.80%
Stationary motors..	4.62	14.22	16.30
Other service	2.95	9.12	13.90
Total	100.00	100.00	100.00

The census of 1902 shows a more detailed report on the class of service rendered by the central stations than in the partial report of 1897, and that only one-third of the companies were supplying current for motor service in 1902. The percentage of the 2,805 private stations and the 815 municipal stations rendering each class of service was as follows:

	Private Stations	*Municipal Stations*
Arc lighting:		
Commercial	59.5	43.3
Public	64.5	87.1
Incandescent lighting:		
Commercial	98.0	89.7
Public	67.5	73.7
Motor power:		
Stationary	34.8	14.5
Electric railway	5.6	0.2
Other services	5.4	1.1

Water Power Development—Factory Installations—1822-1880

The first great water power development in the United States was made on the Merrimack River in 1822 near Lowell, Mass., followed by similiar developments on the same river at Manchester, N. H., and Lawrence, Mass.

The beginning of water power development at Niagara Falls was in 1861, when a canal was constructed and in subsequent years water was delivered to many factories. In 1881 a central powerhouse was built, and the energy therefrom transmitted to several factories by means of belts, ropes and shafts.

By 1880 there was an aggregate of 1,250,000 hp of water power in the United States, the factories served all being located at the site of the water power.

First Hydro-Electric Central Station—1882

On September 30, 1882, the world's first water-driven electric central station was placed in successful operation at Appleton, Wis. Two paper mills and a residence were the first customers of this station, but within a few months several additional mills, a hotel and many residence customers had signed up for electric service. The original water wheel measured about 42 inches in diameter, operated under a ten-foot head and at a speed of 72 rpm. Two Edison "K" dynamos were used, each dynamo being capable of lighting 250 sixteen cp lamps, equivalent to a rating of about 12½ kilowatts. There were no voltage regulators, and the operators depended upon their own eyes to gauge the proper brightness for the lamps. There was no fuse protection. There were no meters, and customers were charged on a lamp basis per month, regardless of the hours of use. Service was from dusk to dawn. Distribution lines were of bare copper wire. The original customers paid about 33 cents per lamp per month. Labor for installing fixtures was 25 cents per hour.

As with most of the infant organizations financial worries continually faced the company's operations. Even with high prices, high rates and low labor costs the utility found hard sledding.

The company's 1894 annual report showed that the company, after 12 years of operation, owed some $96,000. The treasurer's report explained some of the difficulties as follows:

"Our income has been reduced very considerably in wiring because we could not afford to buy the material and because of the establishment of a new firm competing with us and cutting rates regardless of profits. The new lighting company also offered to wire all customers for nothing.

"The disasters of the past year have been the commencement of a suit against the company for $28,000 of our notes. By reason of this suit in which there was an attempt to put us into the hands of a receiver, we lost our credit. Under such circumstances I was obliged to default the interest on our bonds and a majority of our stockholders have commenced proceedings of foreclosure."

Still, the spirit of initiative and progress was not lacking in this first commercial hydro-electric company, for the treasurer ended his report with these words of optimism:

"To be effective and to meet competition we must build a new and modern station and increase our water power capacity which will cost about $24,000, for the load during the winter has been greater than our capacity."

The Keokuk dam and power plant in 1913 brought new designs in water wheels and turbines, the forerunner of

all modern low head vertical units. The multiple runner units at that time had efficiencies of between 70 and 80 per cent. The Keokuk single runner direct-connected vertical turbines had efficiencies of 90 per cent, and an entirely new type of governor was developed.

Alternating Current Displaces Direct Current

The rapid acceptance of alternating current contrasted with direct current caused considerable concern in the early '90s to the owners of the latter type of equiptment. In 1895 one of the most important topics of discussion in electrical circles was the rapid perfection of the induction motor to the point where it could not be neglected by the central station operator. It was then pointed out that if the claims made on behalf of these motors should be maintained, "continuous (direct) current will be definitely placed in such a serious state of inferiority as to give real cause for alarm to its adherents, and should tend to make them consider the advisability of taking advantage themselves of the new advance rather than to wait for it to be exploited by a rival."

It was another one of the oft-occurring evolutions in the electrical art which presented serious problems to the central stations. At that time it was stated that even between annual meetings of the electrical fraternity the intervals "often witnessed a revolution in the art or its methods."

The record shows, however, that most of the central stations adopted alternating current, and the advance in this form proceeded rapidly, while direct current declined in general use. In the early '90s direct current accounted for 90% of central station capacity, and by 1897 only about 62%. By 1902 the percentage of direct-current capacity had dropped to 39%; in 1907 to 18%, and today less than 1% exists in the electric industry—this small amount being used mainly for railway service.

First Alternating Current—1886

In the first alternating-current plant in America, engineered and built by William Stanley at Great Barrington, Mass., in 1886, it was demonstrated how electric power could be generated at a low voltage, transformed into a higher voltage, transmitted at the higher voltage, retransformed to a lower voltage, and used at this voltage as might be required. Without this means of adapting voltage to varying requirements, and of maintaining it substantially constant, irrespective of the load, the enormous development and progress in the transmission and distribution of electric energy could not have taken place. Stanley at the age of 30 had conceived his idea of the manufacture of electric power in some suitable location, and transmitting and distributing it to points of consumption by the use of alternating current. He was determined to find out whether there were any voltage limitations in sight and, in 1892 when 2,000 volts was the highest line potential, he designed in Pittsfield, Mass., transformers and a line of 15,000 volts. He connected his line to the 15,000-volt line, sent the higher voltage current around a farm and back to the same transformer house, then retransformed the line potential to 1,000 volts, and operated the distribution transformers of the local company.

THE COMMERCIAL BIRTH OF THE PUBLIC UTILITIES

Some Historical Dates

Year	
	Water Supply
Jan. 27, 1801	Philadelphia Water Works.
	Gas Supply
Apr. 1812	London & Westminster Gas Light & Coke Co.
Feb. 17, 1817	Gas Light Co. of Baltimore.
1865	Natural gas—Fredonia (N. Y.) Gas Light & Water Works Co.
	Steam Railroads
Sep. 26, 1825	Stockton & Darlington Ry. (Stephenson, England).
May 22, 1830	Baltimore & Ohio R. R. — Ellicott's Mill.
May 10, 1869	Transcontinental — Union Pacific — Central Pacific.
	Telegraph
May 24, 1844	Morse — Baltimore to Washington.
May 15, 1845	Magnetic Telegraph Co. New York to Philadelphia.
1846	Electric Telegraph Co. (England).
	Telephone
Mar. 10, 1876	Bell — 109 Court St., Boston.
Apr. 4, 1877	Boston to Somerville.
May 1877	Bell Telephone Association (Unincorporated).
Jan. 25, 1915	Transcontinental line.
	Electric Supply
	Arc Light
Jan. 1879	Brush dynamo — First one shipped to Dr. Longworth, Cincinnati, 4000 cp.
Apr. 29, 1879	First public street lighting, Public Square, Cleveland, Ohio, 12 lamps, 2000 cp.
Sep. 1879	First Arc Central Station, California Electric Light Co., San Francisco, Calif., (Two Brush dynamos, 22 2000 cp. arc lamps—Rate $10 per week per 2000 cp. arc lamp midnight schedule).
	Incandescent Light
Oct. 29, 1879	First Edison carbon lamps, Menlo Park, N. J.
Sep. 4, 1882	First Edison steam central station—Edison Electric Illuminating Co. of N. Y., 257 Pearl St., N. Y.
Sep. 30, 1882	First Edison hydro central station—Appleton (Wis.) Electric Company.
1905	Gem lamp (Willis Whitney).
1906	Tantalum lamp (Werner von Bolton).
1907	Tungsten lamp (Alexander Just and Franz Hanaman).
1913	Gas-filled Tungsten lamp (Irving Langmuir).
1938	Fluorescent lamp.
	Electric Power Transmission
1886	Electric transformer (William Stanley).
1889	First—Willamette Falls to Portland, Ore., 4000 volts—13 miles.
1892	Polyphase—step-up 2400 to 11,000 volts—Mill Creek to Riverside, Calif., 22 miles.
	Electric Railway
Jul. 31, 1884	Cleveland. (Bentley & Knight. Slot conduit.)
May 4, 1888	Richmond, Va. (Sprague. Trolley.)
Jan. 1, 1898	Interurban—Anderson to Alexandria, Ind. (Henry.)
	The First Utility Regulating Commissions
	Railroad
June 1839	Rhode Island
Dec. 1844	New Hampshire
Feb. 4, 1887	Interstate Commerce Commission
	Electric Light and Gas
Jun. 11, 1885	Massachusetts
	Modern Public Service Commissions
Jun. 6, 1907	New York
Jul. 9, 1907	Wisconsin
	Water Power
Jun. 10, 1920	Federal Power Commission

In the early '80s the average size of the arc lighting system dynamo was about 10 kilowatts, and a 50-kilowatt dynamo was considered large. The efficiency of these dynamos was about 40 per cent. The relatively large capacity of Edison's 120-kilowatt, 90 per cent efficient dynamo, earned the name of "Jumbo." Even well into the '90s the average central station consisted of a single high-speed engine of 50 to 150 horsepower, with an arc dynamo of 25 light capacity, and an incandescent dynamo of 500 light capacity.

Table II shows the progress in the increased size of dynamos and generators in steam stations, and also the growth in size of the largest central stations, from 1882 to present times. Figs. 1 and 2 graphically illustrate the increases in size of both steam and hydraulic generators. From the original Edison "Jumbo" dynamo of 120 kilowatts to the 208,000 kilowatt generator in today's State Line plant near Chicago, is a long way; it would take 1733 Jumbos to equal the capacity of the State Line plant generator. A generator of 208,000 kilowatts does the work of 12 million men, working 8 hours each.

Even in 1888 when the Edison Electric Illuminating Company of New York erected its second generating station, on West 26th Street, and its third on West 39th Street, the steam engine units had reached a maximum of only 200 horsepower. When the Duane Street equipment was installed in May, 1891, engines were of 2500 horsepower, each with a pair of 800-kw dynamos.

TABLE II—GROWTH OF REPRESENTATIVE ELECTRIC GENERATOR SIZES AND STEAM POWER PLANTS 1879-1942

	Maximum Generator Size Kilowatts	*Plant Capacity Kilowatts*	*Plant*
	Reciprocating Engines		
1879	20	.....	Typical arc dynamo, 40% efficient
1882	120	720	Pearl Street, New York. Edison's "Jumbo" dynamos, 90% efficient
1888	200	3,200	Adams Street, Chicago
1889	250	3,276	Sansom Street, Philadelphia
1890	1,250	4,850	Albany Street, Boston
1893	1,600	7,600	Duane Street, New York
1897	2,000	3,100	Bay Ridge, Brooklyn
1898	2,750	30,250	96th Street, New York
1899	3,500	56,000	Waterside, New York
1901	5,000	45,500	74th Street, IRT, New York
1903	12,000	120,000	Fisk Street, Chicago
	Turbines		
1904	5,000	.....	Fisk Street, Chicago
1905	9,000	.....	
1906	12,500	.....	
1912	20,000	40,000	Northwest, Chicago
1915	45,000	180,000	Conners Creek, Detroit
1924	50,000	150,000	Trenton Channel, Detroit
1925	60,000	160,000	Crawford Avenue, Chicago
1928	94,000	94,000	Long Beach No. 3, California
1929	165,000	610,000	Hell Gate, New York
1929	208,000	208,000	State Line, Indiana

Improvement in Steam Production Efficiencies

The Pearl Street plant of 1882 was able to generate a kilowatt-hour—a term not then in use in this country—from the burning of about 10 pounds of coal. This represented a remarkable improvement over the average thermal efficiency of the engines then producing current for arc lighting. There are records of some

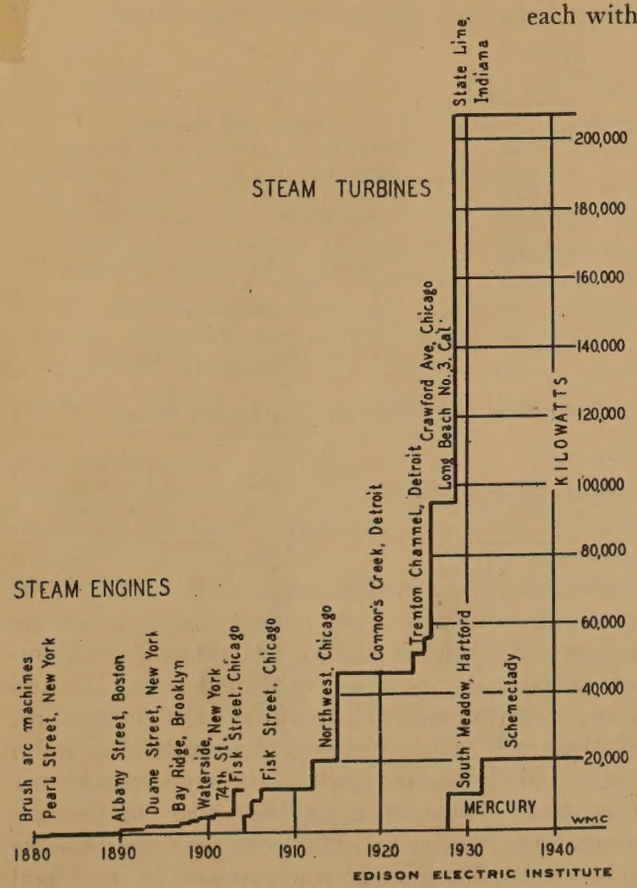

Fig. 1—Growth in Size of Steam Engines and Turbines

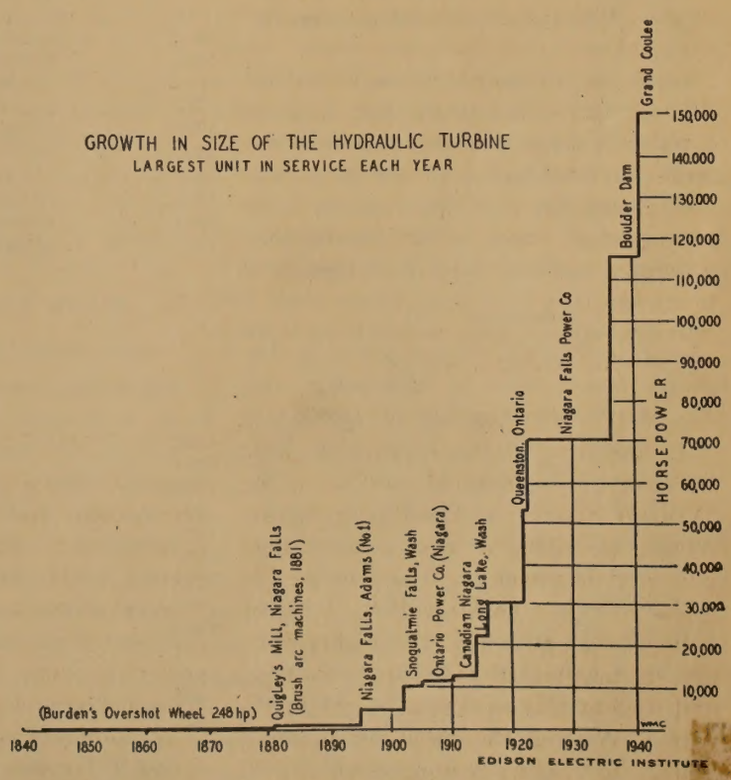

Fig. 2—Growth in Size of Hydraulic Turbines

small plants of the 1880s and 1890s using as high as 30 pounds of coal per kilowatt-hour.

The amount of coal required per unit of energy varied materially with the percentage of load on the early dynamos. In a study made in 1895 such a relationship was shown for a number of central stations of different sizes. The lesson learned from the investigation was the necessity for so proportioning the generating units of a station as to admit of each unit being worked at as nearly full load as possible.

In Table III are shown, in condensed form, the approximate amounts of coal burned per kilowatt-hour at selected loads on the dynamos for the larger efficient dynamos, medium size and the smallest and most inefficient.

It was apparent in the electric census of 1917 that the group of smallest steam power plants were still requiring as much as 18.26 pounds of coal per kwhr compared with 2.49 pounds for the largest plants.

Table IV shows a series of figures giving the thermal efficiency of (a) prime movers from the time of the Newcomen engine (1770) to the mercury vapor turbine (1930); (b) of efficiency records of selected best-performance electric power stations, at intervals in which substantial improvements were achieved; and (c) the average thermal efficiency of all electric power plants in the country from 1882 to 1941. Most of these early records are from the compilations published from time to time by George Orrok. This trend is shown graphically in Fig. 3.

From the 10 pounds of coal used in 1882 to 0.75 pound in the best stations of today is truly a remarkable achievement—but observation of the long-time trend shows that the improvements have been gradual, and each decade has recorded a material gain in efficiency.

Pulverized Coal

In the fall of 1918 there began in the Oneida Street plant in Milwaukee experiments in the burning of powdered coal, under a 468 hp. boiler that had already seen 22 years of service. The Bureau of Mines cooperated in the work. Engineers predicted failure and questions were even raised as to the reliability of the published experimental results. However, the company decided to venture on a new power plant using only powdered coal, and thus the Lakeside Plant in Milwaukee, which began operation in 1920, was the first such plant in the world. The increase in steam production efficiencies completely justified the new method, and the succeeding years saw most of the new power plants throughout the country installing pulverized coal equipment.

The trend to pulverized coal increased to such an extent that of new boiler equipment installed in the five years 1936 to 1941 in central station plants, 90% of the steam generated is from powdered coal and 10% from stoker fired boilers.

Table III

Year 1895

Type of Engine	*Coal Burned Per Kilowatt-Hour Percent Load on Dynamo* 100% Pounds	50% Pounds	20% Pounds
Compound condensing engine, 2000 hp.	2.0	3.2	6.0
Compound non-condensing engine 300-800 hp.	4.5	7.0	14.0
Simple non-condensing engine 100-200 hp.	8.0	14.0	30.0

Mercury Vapor Turbines

At a meeting of power engineers in December, 1941, mercury as a thermal medium for power generation was declared to have "come of age," after 28 years of persistent experimentation. In 1928 the first mercury turbine, of 10,000 kw capacity, was installed in the South Meadow Station at Hartford, Conn. Four years later a 20,000-kw mercury turbine was built at Schenectady by the General Electric Co. A third was in-

Table IV—Gain in Thermal Efficiency in Steam Engines and Power Plants

Efficiency of Prime Movers

Year	*Prime Mover*	*Pounds Pressure*	*Equivalent Btu. per Kwhr.*	*Percent Thermal Efficiency**
1770	Newcomen engine	15	416,000	0.82
1900	Nordberg engine	215	19,200	17.75
1922	Turbine	265	18,000	19.00
1930	Mercury vapor turbine—Hartford, Conn.	140	10,300	33.10
1935	Port Washington power plant	1,245	10,850	31.50
1941	Mercury vapor turbine—Kearny, N. J.	350	9,175	37.30

Efficiency Records of Some Best Performance Electric Power Steam Plants

Year	*Btu. per Kwhr.*	*Percent Thermal Efficiency**	*Equivalent Pounds of coal at 13,800 Btu. per pound*	*Plant and Location*
1882	138,000	2.48	10.00	Pearl Street. New York City
1902	41,250	8.28	3.00	Waterside No. 1. New York City
1907	36,800	9.28	2.66	Waterside No. 2. New York City
1912	33,200	10.29	2.40	Lake Shore. Cleveland, Ohio
1917	20,040	17.05	1.45	Conners Creek. Detroit, Mich.
1922	18,674	18.29	1.35	Lakeside. Milwaukee, Wisconsin.**
1925	14,250	23.97	1.03	Philo. Ohio
1928	12,500	27.30	.91	Columbia. Cincinnati, Ohio
1934	11,900	28.71	.86	Gilbert. New Jersey
1937	10,669	32.02	.77	Port Washington. Wisconsin

Average Thermal Efficiency of all Electric Power Plants in United States

Year	*Btu. per Kwhr. U. S. Average All plants*	*Percent Thermal Efficiency**	*Equivalent Pounds of coal at 13,800 Btu. per pound*
1882	138,000	2.48	10.00
1887	125,000	2.74	9.05
1892	108,000	3.17	7.75
1897	96,000	3.56	6.95
1902	92,500	3.70	6.70
1907	74,500	4.59	5.40
1912	60,600	5.64	4.40
1917	45,500	7.50	3.30
1922	34,500	9.90	2.50
1927	25,400	13.45	1.84
1932	20,700	16.50	1.50
1937	19,700	17.35	1.43
1941	18,600	18.40	1.35

* 3,412 BTU, equal one kilowatt-hour.
** First pulverized coal plant.

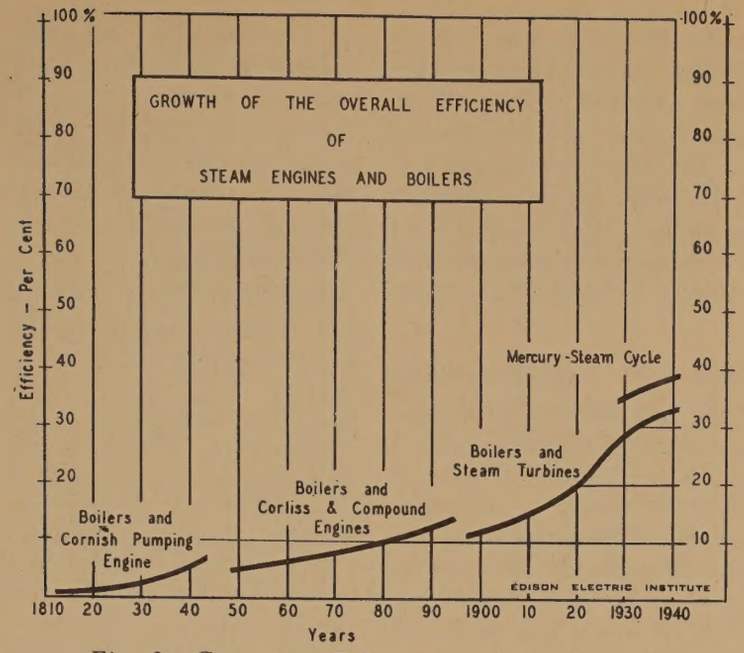

Fig. 3—Growth in Efficiency of Steam Power

stalled in the Kearny Station of the Public Service Electric & Gas Co. in 1940. This unit has shown a heat rate of 9,175 Btu. per kwhr in its operations of 1941-1942. H. N. Hackett, of the General Electric Co. has stated that future applications may attain better than 50 per cent thermal efficiency.

The Shift to Large Plants—Costs and Revenues per Kwhr Decrease

The electric industry recognized early the economic and operating advantages of large generating plants serving considerable territory over numerous small separated plants. By the first decade of this century the gradual change to unified and concentrated electric power generation from large capacity plants had begun, with consequent scrapping of the many small unefficient generating plants.

The 1917 electric census of the U. S. Bureau of the Census demonstrated the great progress that has been made in this direction by that year. Average costs and revenues per kilowatt-hour of some 5,124 central stations were given in a special section of the census, according to the size of the plant in current output. The series covered plants with outputs below 200,000 kwhr up to those producing 200 million kwhr and over, with separate data for steam, hydro, oil-burning and gas-burning plants. Not all of the larger plants were given, as the census could not disclose individual plant figures, but enough were given to show the full trend from small to large.

The largest plant group received from 1.63 to 2.50 cents per kilowatt-hour in revenue; the medium size plant group received from 3.50 to 5.50 cents per kwhr; and the smallest plant group received from 7.5 to 10.00 cents per kwhr, all of these figures being for steam generating plants. Revenues of the hydro plants were generally lower than those of the steam plants, but the range from large to small plants was practically in proportion to the steam plants. The oil generating plants ranged from 3.20 cents for the largest size group to 12.20 cents per kwhr for the smallest size group.

Developments in Electrical Transmission

The possibility of transmission of electricity was pointed out as early as 1850. It is claimed that in 1858 in the artillery works at St. Thomas d'Aquin, France, electricity for the first time was transmitted for driving a commercial machine.

Practical experiments by Gramme in 1873 are credited with being the first convincing demonstration of the possibility of employing electric current for transmitting energy from one place to another. His experiments consisted of transmitting current from a machine working as a generator to a second machine about 550 yards distant, working as a motor driving a pump.

In 1882, Marcel Deprez built the first long-distance transmission line from Miesbach to Munich, a distance of 37 miles. It was built purely for experimental and demonstration purposes, 2400-volt direct current being used. In 1886, Deprez completed a line from Criel to Paris, about 25 miles, transmitting 20 amperes direct current at a potential of 7500 volts. Transmission efficiency was about 32 per cent.

The first alternating current transmission system was constructed in Italy in 1886, and known as the "Cerchi Tivoli-Rome" plant. Equipment at the station consisted of two 150 hp steam-driven, single-phase Ganz generators designed to operate at 112 volts. Transformers having a ratio of 1:18 were used to step this voltage up to 2000, at which voltage energy was transmitted to Rome, a distance of 17 miles.

Early A-C Hydro-Electric Installations

In 1889 the first alternating-current hydro-electric installation was made at Oregon City, Ore., by the Willamette Falls Electric Company, power being transmitted 13 miles to Portland, Ore. The installation consisted of two 300-hp water wheels belted to single-phase generators. Capacity of the power house was 720 kilowatts, and the line was of 4000 volts.

In the winter of 1890 the San Miguel Consolidated Gold Mining Company installed on a fork of the San Miguel River near Ames, Colo., a power house of two 150-kilowatt single-phase Westinghouse generators, directly connected to Pelton water wheels, and transmitted the power at 3000 volts to the Gold King Mine, a distance of three miles. This mine was situated at an elevation of 12,000 feet, where the cost of fuel had been so prohibitive as to force the company into bankruptcy in 1888. L. L. Nunn, an attorney retained by the owners, found that there could have been a handsome profit if power could have been furnished at not more than $100 per horsepower-year!

Nunn felt electrically transmitted power would solve the cost problem, but he sensed the limitations of direct current and had faith in the ultimate success of alternating current. While selecting the electrical apparatus, he encountered little but incredulity and ridicule. Eastern investors in the enterprise were annoyed by predictions of prominent engineers, and discouraged by their insistence, that the experiment would prove a failure. In the construction and operation he ran into difficulties caused by ice at

40 degrees below zero; by speed control over unusually high water pressure (the equipment was a 6-foot Pelton wheel, operated at 320-foot head); by avalanche; by blizzard; by electric storms unknown at lower altitudes; and by many other troubles later generally forgotten.

Everything was extremely simple from waterwheels to motors and, except for lightning interruptions, the plant ran smoothly and steadily for 30 days without a stop. The announcement made in the East by associates of the enterprise that at Telluride, Colorado, electric power was being successfully transmitted nearly three miles over No. 3 copper wires with less than 5 per cent loss was received with incredulity.

Following its pioneer installation the company made practical experiments as early as 1895 with tests of pressures up to 60,000 volts, and in 1896 a 10,000-volt underground transmission line was put in operation at the Gold King Mine.

Despite the successful operation of these two early systems, an electrical engineer from California at the International Electrical Congress held in Chicago in 1893 made this statement:

"I wish to say definitely that to the investor in California today, the successful machine for long distance transmission of power electrically exists only in the minds of the inventors and promoters, or in some beautiful advertisement."

In 1891 the San Bernardino Light & Power Company constructed a 5,000-volt transmission line from its power house at Pomono, Cal., the line running 28 miles to San Bernardino. In 1892 the line was increased to 10,000 volts.

At the Ames, Colo., installation experiments and tests were made between 1890 and 1895, of pressures as high as 60,000 volts. At the Pomona project, the original voltage of 5,000 in November, 1892, was increased to 10,000 in February, 1893, and on May 2, 1893, by connecting transmission lines all in series, 120 kw was carried 42 miles with a transmission efficiency of 60 per cent, at that time a great achievement and an indication of the possibilities of electric transmission of power.

In 1891 power was transmitted from a water fall station at Lauffen to the city of Frankfort, a distance of about 100 miles. The transmission line used 30,000 volts, far above anything that had been used previously. This line achieved a great deal of publicity, but the installation was not a permanent one, being more or less an experiment to advertise an exposition going on in Frankfort.

The Lauffen-Frankfort line was 3-phase. Following its opening, there began two major technical battles—one of 3-phase versus 2-phase, and the other of frequencies. The phase controversy was stopped by the master stroke of Charles F. Scott, with his "T-connection" for transformers to connect 2-phase circuits to 3-phase circuits in balanced power relation.

First Polyphase A-C Transmission Lines

In 1892 the first commercial 3-phase alternating current installation, with a 10,000-volt transmission line 23 miles in length from Mill Creek to Riverside, Cal., was made. The installation consisted of two 250-kilowatt 2400-volt Y-connected generators, driven by Pelton Wheels. The plant and line were still in operation as late as 1934.

The year 1895 marked the beginning of the modern central station era and the recognition of the supremacy of polyphase alternating current for generation and transmission when the 5000-hp units began operation at Niagara Falls.

The electric equipment installed by the Niagara Falls Power Company in 1895 was unique in many respects. Primarily, it was unique in that it was intended for power instead of light, as had been most of the preceding installations. It was by far the largest electric power installation of the time. The methods adopted were new and untried—at least on the scale attempted at Niagara—namely, alternating current, polyphase. Practically all of the users of Niagara service were power users. The first user was the Pittsburgh Reduction Company, now the Aluminum Company of America, whose plant was started on August 26, 1895.

The Niagara electric generators were four times the capacity of the largest generators previously constructed. They were rated and were capable of carrying 5000 hp.

The first Niagara-Buffalo transmission line on the American side of the Niagara River went into service during the fall of 1896. The line was a relatively short one, only about 22 miles from the step-up station in Niagara to the step-down station in Buffalo. The voltage was not high—11,000 volts, 3-phase; other plants were at the time transmitting power at higher voltages. However, in some aspects the transmission was of historical interest. In the amount of power transmitted and in the importance of the service rendered, the Niagara-Buffalo transmission transcended anything that had been attempted previously. The first load in Buffalo was that of the street railways. Continuity of service was essential. It soon developed that the success or failure of Niagara power in Buffalo depended on keeping the supply continuously available in Buffalo.

Lightning was a formidable enemy, and required great research and development of protective insulation and arresters. The line was especially liable to interruptions owing to the severity of lightning storms on the Niagara frontier. Improvements came gradually but surely, and in recent years the company has gone the span of an entire year without a single interruption from lightning or any other cause.

Paul M. Lincoln, now Director, School of Electrical Engineering, Cornell University, who was electrical engineer and operating superintendent of the Niagara Falls Power Company from 1896 to 1902, had this to say about overcoming difficulties of this company's early transmission line:

"I might go on indefinitely giving instances of the difficulties we encountered on this early power transmission. They all lead to one conclusion: we were pioneers and we suffered the fate of all pioneers. The road we were traveling was not yet illuminated by the light of experience. We had to grope our way. We were not wholly unsuccessful in lighting the way for others to follow. The Niagara-Buffalo transmission was a success both from a financial and from an engineering standpoint. The battle for continuity of service was waged and won. It has always been a matter of no little self-satisfaction that we at Niagara have helped to blaze the trail that since then has become a much traveled highway."

Determination of Frequency

The development of hydro-electric power on a large scale at Niagara Falls forced the adoption of alternating current, only to be followed by great uncertainty as to the frequency to be used. Some authorities recommended 16.66 cycles per second. Other authorities felt convinced that eventually much of the vast power to be developed at Niagara Falls would have to be applied to continuous current machinery. The controlling engineers and executives of the project decided to launch it on a frequency of 25 cycles. As pointed out by Edward Dean Adams in his history of Niagara Falls, the 25 cycle frequency was a compromise.

Much work of all sorts remained to be done in the new electrical industry. Hydro-electric power in abundance was available on the Pacific Coast and the Intermountain Region involving trans-

missions to available markets over long distances. There quickly developed a need for standardization in voltage and current wave forms. Various frequencies were tried between the extremes then in use, 133 and 25 cycles. 40 cycles per second was tried at Portland, Ore.; 50 at Los Angeles and 60 at San Francisco. By 1915 the hydro-electric power transmission practice was stabilized at 60 cycles in the Far West and elsewhere.

High Tension Transmission Lines in 1908

The year 1908 saw the first evidence of the feasibility of transmission of voltages above 60,000 and in that year the first 100,000 volt line was installed. This was in the state of California, where the greater part of early installation of high tension transmission took place. This was natural, from the abundance of water power throughout the state, and from the fact that coal had to be imported from British Columbia or Australia, and cost in carload lots about $7 per ton. After 1895 oil became the standard fuel in California, but even as late as 1914 the price of oil, under ordinary conditions, was only 14 per cent cheaper than coal on an equivalent heat basis.

The first 100,000-volt long distance transmission line in the United States was installed by the Great Western Power Company from its Big Bend Plant, at Las Plumas, on the Feather River in northern California to Oakland, a distance of 155 miles. The Big Bend Plant was put into operation December 22, 1908, with four 10,000-kva units. The turbines were I. P. Morris 60-inch Francis vertical inward-flow machines, designed to operate at a speed of 400 rpm under a head of 525 feet. The 100,000-volt main trunk transmission line consisted of a single line of galvanized-steel towers, carrying two 3-phase circuits on suspended insulators, and included 1044 standard towers, and numerous smaller towers.

Commercial Development of the Transformer

In the eight years from 1894 to 1902 the maximum size of the transformer increased from 10 kilowatts to 2750 kilowatts, an increase of 275 times. The manufacture of these units also increased incredibly in this period, the total annual output increasing from 300 or 400 kilowatts to 250,000 kilowatts. The average size of the transformers increased from 10 kilowatts to 250 kilowatts in the period.

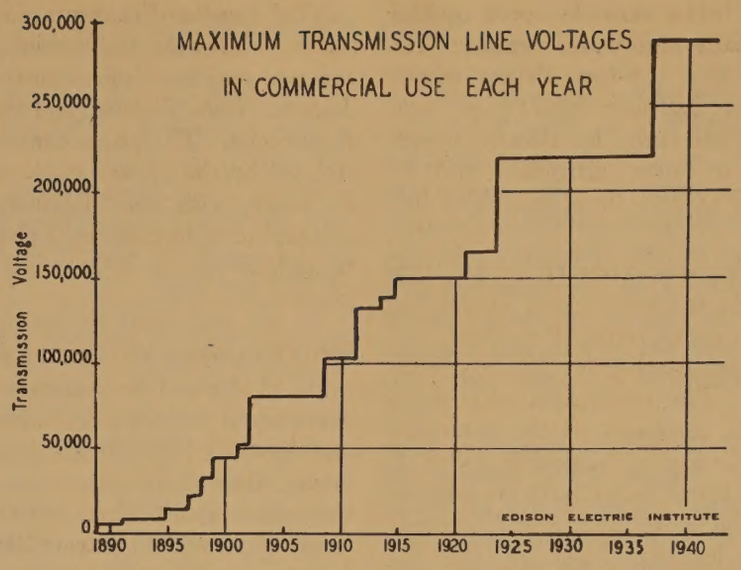

Fig. 4—Growth in Transmission Voltages

In a paper presented at the International Electrical Congress in St. Louis in 1904, Dr. F. A. C. Perrine said that natural groups of transmission length and voltage were somewhat decided by the manufacturers of machinery, who had presented as preferable certain available voltages. Above 2400 volts, "where transmission really begins" the first voltage commonly being employed in 1904 was 6600 volts, established as a standard by the needs of the lighting plants in the great cities. The next higher voltage, and practically the first one for which step-up transformers were used, was 15,000 volts.

The next step was to 25,000 volts, which was the highest figure reached without special study of insulators, switches and lightning arresters. A voltage of 33,000 was employed in a number of plants built about 1900, and at that figure special difficulties due to line capacity, insulator size, erratic lightning-arrester effects and switching began to make themselves seriously felt.

Above 33,000 volts the standard voltage in 1904 was called 60,000 volts, but the majority of plants actually operated at about 50,000 volts, being unable to operate at the 60,000-volt pressure on account of the character of the line insulators installed.

For years the power transmission industry was virtually forced to be content with 50,000 to 60,000 volt line insulators, the single pin-type insulator being thus limited, and which would not stand up under higher voltages. With dramatic suddenness the invention of the suspension type insulator made possible higher voltages for transmission lines. In 1908 in Michigan on a short line it was found that by the use of the latter type of insulators transmission of 110,000-volt, 3-phase, current was entirely feasible.

The General Electric Company reported the increase in voltages of transformers, based on orders received, as follows:

Year	*Volts*	*Year*	*Volts*
1891	3,000	1907	104,000
1892	6,000	1909	133,000
1894	12,000	1911	140,000
1896	22,000	1912	150,000
1897	33,000	1919	166,000
1898	44,000	1920	220,000
1900	55,000	1926	240,000
1901	80,000	1933	280,000

The beginning of operation of any of the above voltages naturally lagged one or two years behind the years given.

The number of available voltages continued to increase, until by 1922 there were some 30 different voltages classed as "normal" secondary voltage of the step-up transformers. In order to reduce the burden on the electric industry, simplify the practice, and encourage the development of standard apparatus and especially to facilitate interconnection of systems, certain voltages were adopted as standard by organizations representing the power industry and the manufacturers. These standard voltages were:

33,000	111,000
44,000	132,000
66,000	154,000
88,000	220,000

The first 60,000 volt transmission line was installed by the Bay Counties Power Company, between Colgate Power House, on the Yuba River and Oakland, a distance of 142 miles. The line was a double circuit. It was energized on April 27, 1901.

Early Price History of the Electric Light

When the "First District" of the Pearl Street Plant in New York City was lighted up in September, 1882, no charge was made for the use of the light. The directors were of the opinion that owing to the irregularity of the light, resulting from the imperfect governing of the engines, no charge should be made until the station was running light satisfactorily to their own engineers.

Although the British Electricity Supply Act of August, 1882, defined the "kilowatt-hour" as the Board of Trade unit for which the consumer had to pay for current, the term did not come into use in this country until 1889, the year in which the "watt" was given universal adoption by the International Electrical Congress held in Paris. From 1880 to 1884 the unit of current in the United States was termed the "weber,". In 1884 the name was changed to "ampere," and a unit of electrical power was called the "volt-ampere."

By the end of 1882 Edison had his engines running smoothly and the Edison chemical meter was put into use in 1882. This meter consisted of an electrolytic cell containing a solution of zinc sulphate with zinc plates for electrodes or terminals. It was limited to the measurement of direct current, and since all energy from the Edison stations of that day was supplied at a single constant voltage, it was satisfactory for some time to meter only the ampere-hour consumption. The company thereupon began early in 1883, to bill its customers, announcing:

"It is the present intention to make the bills for the light payable monthly, as it is the custom with gas bills, and to make the charge on the basis of $1.00 per 1,000 candles, which is equivalent to about the present price of gas ($2.25 per 1,000 cubic feet)."

A later bulletin of the Edison company, in 1883, stated:

"Our charge for light in the First District is at the rate of 1 and 1/5th cents per lamp per hour, consequently the product obtained by multiplying this price into the number of lamp hours shows what the consumer's bill for the light ought to be."

This rate would be the equivalent of 24 cents a kilowatt-hour.

Edison figured that "a lamp of 16-candlepower was the equivalent of a gas burner supplied with 5 feet of gas." Five feet of gas, at the prevailing rate of $2.25 per 1000 cubic feet, would cost 1.125 cents, so the first Edison charge of 1.2 cents per 16-cp lamp hour was a close equivalent. The price included the cost of the lamp.

For a 16-cp lamp burned 3 hours a day, the monthly cost at the Edison rate of 1.2 cents per hour would be $1.08, or $13 per year.

In the year 1883 the consumers were using an average of about 16 to 20 lamps each, of 16 and 8 candlepower. There were about 4 of the "A" (16-cp) lamps for every 3 "B" (8-cp) lamps on the lines. Consumers' bills ran to about $10 per month in the short evening summer months and about $15 and more in the winter months. The following shows a record of some months of Pearl Street plant operation in 1883, as to number of consumers, number of lamps and billings to consumers:

Month 1883	*Average No. of Consumers*	*Lamps In Use*	*Billings*	*Average Per Consumer*	*Average Per Lamp*
June	423	6,947	$5,204	$12.30	$0.75
July	440	7,687	4,530	10.30	.59
August	449	8,082	4,609	10.20	.57
September	463	8,395	5,062	10.90	.60
October	490	9,368	7,072	14.40	.75

The first Edison lamps were made "8 to the horsepower," equal to about 100 watts each, with an average lighting efficiency of 1.1 lumens per watt. Before Pearl Street opened they were being made "10 to the horsepower" and the wattage was 75, and had 2.25 lumens per watt initially.

In 1890 the Edison company in New York reduced its charge to 1 cent per lamp hour, the equivalent of 20 cents per kilowatt-hour. Discounts were offered for large customers, and the company was unique in that it published its complete schedule of rates and discounts.

Edison Wanted to Sell Light

Edison did not favor rates for current, as he wanted to sell "light." He said:

"The reason I wanted to sell light instead of current was that the public didn't understand anything about electric terms or electricity and had no confidence that they could ever learn; but they did understand light and it was light they paid for and we could make explanations which they could comprehend.

"Another reason I did not want to sell current was that from my experiments I knew that the incandescent lamp was only the beginning and that there were great possibilities of enormously increasing its economy, and I thought that the pioneers should reap some reward for these improvements. It was my idea that all the benefits which improvements in the lamp should attain, one-half should be given to the public and one-half given the company. But for some reason after a few years the selling of current was introduced, thus destroying all chances of the company's gaining any benefits from improvements; in fact such improvements were a disadvantage, which to my mind is a poor business policy for the company and the public."

In October, 1898, the Edison Company in New York City changed its rates to a "kilowatt-hour" basis, of promotional form, as follows: First hour's use, 20c per kwhr; second hour, 15c; third and fourth hours, 12c; and excess over four hours, 5c.

The spread to kilowatt-hour rates was rapid, being augmented by the development of accurate meters for measuring current used by the customers, and increasing power sales.

Many companies, especially the smaller ones, established flat rates per kilowatt-hour, regardless of the length of use or the quantity of current. The more progressive companies adopted load-factor rates based on the hours of use, and also quantity discounts for increased use.

A report of the United States Commissioner of Labor published returns of 952 electric central stations in the year 1897. The report gives for all stations the rates then in effect for both lighting and power. There were few companies supplying electric power, being only the larger sized companies.

A weighted analysis of the various types of rates charged by these utilities indicates the trend to kilowatt-hour rates within the years from 1890 to 1897. The following gives a condensed summary of the number of utilities and the average price charged according to the type of rate. A utility may have had two or more of these schedules in effect, and thus would appear under each of such types. All average prices are weighted by the size of the utility.

Rates for Incandescent Lighting:

(a) Rate per kilowatt-hour—426 utilities, or 45 per cent of the total; average rate 14.51 cents per kilowatt-hour;

(b) Rate per lamp per year (16-cp. equivalent)—500 companies, 53 per cent; average rate $8.10 per lamp per year;

(c) Rate per lamp hour—91 utilities, 10 per cent; average rate 0.63 cents per lamp hour;

(d) Rate per ampere hour—116 utilities, 12 per cent; average rate 0.90 cents per ampere hour.

Rates for Arc Lighting:

(e) Rate per arc lamp per year—722 utilities, 76 per cent; average rate $87.52 per arc lamp per year. In terms of rate per kilowatt-hour, averages 8.50 cents.

Under rate (e) the total number of lamps, the average hours burned per year, and the average price per lamp are as follows:

	Number of Lamps	*Average Hours per Lamp*	*Average Price per Lamp*
To commercial customers	25,934	2,108	$95.36
To municipality for street lighting	90,824	3,430	85.30
To all users	116,758	3,137	$87.52

Developments in Gas and Electricity Price Trends

As pointed out, Edison's first charge in 1882 for electric light was based on an equivalent cost for gas lighting, i.e. a 16-cp lamp being the equivalent of a gas burner supplied with 5 cubic feet of gas. The prevailing cost of gas in 1882, on which the charge was based, was $2.25 per 1000 cubic feet.

Gas lighting in New York City began in 1824 when the first private lighting was turned on—and public street lighting began in 1828. The original charge for the former was $10.00 per 1000 cubic feet, and for the latter $24 for a lamp-post and $8 per lamp per year for gas. Reductions came quite rapidly, the charge being $9 per MCF in 1828; $8 in 1829 and $7 in 1830. A second company entered the field in 1834 and began to offer lower rates than the original company, of $6 in 1836; $5 in 1838, and $4 in 1839—while the old company continued to charge its $7 per MCF. In 1850 rates were at $3.50 per MCF, and in 1855 down to $2.50. During the Civil War the rate was increased to $3 and to $3.50. In 1879 a rate war took place with the price dropping as low as 75c per MCF for large users, but in 1880 a pool agreement was reached by which a standard price of $2.25 was established—the charge met by Edison with his electric lamp.

Carl Auer invented his famous Welsbach gas mantle in 1885, which produced a light six times better than that of the old flat-flame or slip-tip burner. But the public at first looked upon it as a luxury and did not appreciate the advantages and savings inherent in its use. It was not until 1890 that it came into general use, but it was then too late to halt the progress of the rapidly expanding Edison incandescent electric lamp.

The competition was sufficient to worry the electric people, and even in New York City in the middle '90s there were districts in which the installations of Welsbach gas lamps was greatly exceeding those of the Edison lamps. The gas companies were installing the Welsbach lamps free and maintenance in first class condition was assumed, and were trying to switch over any electric customer whose bill exceeded $15 per month. But perhaps a major reason for the Welsbach spread was the drastic cuts in the rates for gas. In the 90's a bitter rate war developed between the three gas companies and in 1899 the prevailing rate was 50 cents per MCF.

Development in Lighting Efficiency

Three factors concurrently were aiding the Edison lights in keeping abreast with the lowering charges for the gas lights. These were: the price of the Edison carbon lamp, which, from 1880 to 1904, decreased from $1 to 20 cents each; the average efficiency of the lamp, which increased from 1 lumen per watt to 2.8 lumens per watt; and the decrease in the cost of producing current for lighting the lamps, which dropped from an average of 24 cents to 7 cents per kilowatt-hour.

In 1882 one cent would buy 50 lumens (5 candlepower hours) of the original Edison carbon lamp. In 1904 one cent would buy 360 lumens of the improved carbon lamp, or seven times as much light as in 1882.

In 1905 came the Gem lamp, which was 25 per cent more efficient than the regular carbon lamp of that time. It was also in the year 1905 that the rating of incandescent lamps was changed from a candlepower basis to wattage basis. The ordinary 16-candlepower carbon lamp consumed 50 watts of current and was so rated. The 50-watt Gem lamp gave 20-candlepower, both candlepower ratings being their mean candlepower in a horizontal direction. The Gem lamp was made in a number of sizes from 40 to 250 watts, but the 50-watt lamp was the most popular, many million of which were made before the lamp disappeared from use in 1918.

TABLE V—DECREASE IN COST OF LIGHT UNITS FROM 1882

Year	*Lumen-hours* For One Cent*	*Cost per Thousand Lumen-hours*	*Cost in Percent of 1882*
1882	50	20.00¢	100.0
1888	143	7.00	35.0
1894	220	4.55	23.0
1900	300	3.33	17.0
1904	364	3.02	15.0
1905	440	2.27	12.0
1906	501	2.00	10.0
1907	635	1.57	7.9
1912	1020	0.98	4.9
1914	1300	0.77	3.9
1915	1620	0.62	3.1
1923	1700	0.59	2.9
1933	2000	0.50	2.5
1937	2400	0.42	2.1
1942	3400	0.29	1.5

* For candle-power hours, divide by 10.

In 1906 there appeared the tantalum lamp, made with a filament of this metal. It had an average efficiency of about 4¼ lumens per watt. It disappeared from use in 1913.

While the inventors of the tungsten lamp had produced such a lamp in 1904, it was not until 1907 that they were put upon the American market, the first lamp put out being the 100-watt size for 110 volts. The efficiency of this lamp was 8 lumens per watt. Within a short time tungsten lamps of 60, 40 and then 25 watts were being made and sold in large numbers.

In 1911 was introduced the improved tungsten lamp, made with a ductile tungsten. In 1913 tungsten lamps were further improved by operating the filament in an inert gas.

The fluorescent lamp first commercially appeared in 1938 and has already shown considerable improvement in its efficiency after solution of the poor power factor problem, and the price has been lowered seven times in the four years since its introduction.

Major Changes in the Incandescent Lamp

The major changes in the incandescent lamp since its introduction in 1879 have been:

1879...Carbonized thread—carbon filament.
1879...Carbonized paper—carbon filament.
1880...Carbonized bamboo—carbon filament.
1888 ..Asphalted bamboo—carbon filament.
1893...Treated bamboo—carbon filament.
1894...Treated cellulose—carbon filament.
1905...Metallized carbon filament—GEM lamp.
1906...Tantalum filament.
1907...Tungsten filament.
1911...Drawn tungsten wire filament.
1912..."Getters" (chemicals used to improve the lumen maintenance).
1913...Gas-filled tungsten filament lamp.
1937 ..Coiled coil tungsten filament.
1938...Fluorescent lamp.

The combination of increased effi-

ciency in the lamp, reduction in the price of the lamp, and reduction in the price of current has resulted in giving the incandescent lighting user about 70 times as much light today as he obtained in 1882 for an equal amount of money. In other words, the cost of electric light today is less than 1½ per cent of the cost for an equivalent amount of light in 1882. The trend in the increase of number of light-units received for one cent at intervals from 1882 to 1942 has been as shown in Table V.

The figures for the later years are based on the standard 60-watt Mazda lamp; larger wattage lamps have much higher efficiencies than shown, and smaller lamps lower efficiencies. All figures are based on the prevailing lamp prices, lamp efficiencies and rates for current as of the years shown.

Motors and Diversified Electric Service

Even before Edison invented his central station system he was positive that power would eventually be as important as light. In an early notebook (1878) he said:

"It doesn't matter if electricity is used for light or for power. Small motors can be used night or day and small steam engines are inconvenient."

This was quickly recognized by others. For example, in 1881, President Thurston of the American Society of Mechanical Engineers, in his second annual address to that body, referred to Edison's new dynamo which increased efficiencies to 90 per cent from the former 40 to 50 per cent dynamos.

"It follows at once that mechanical power may be transmitted through two such machines, again appearing as mechanical power with a loss of less than 20 per cent. And it follows from this last fact that the distribution of power by electricity is not unlikely to prove *a more important application of this wonderful force than is the electric light.*"

When the Pearl Street plant opened, Edison was already busy designing electric motors for customers' use. A bulletin of the Edison Company of New York in December, 1882, said:

"Regarding the selling of power in the First District, Mr. Edison is now engaged in constructing motors of different sizes. We expect a large demand for power and now that selling of light has been successfully started, special attention will be given to equipping the District with facilities for furnishing power."

But it was not until 1884 that saw the beginning of diversification of electric sales, for in that year the first electric fan motors went on the circuits and various motors were introduced for industrial uses. Diversified power had begun.

By 1886 electric motor power was being sold by a station in Boston. The Daft Electric Power Company, from its dynamos at a central station, was supplying electric power to about 30 motors in various parts of the city.

"It is sold at $150 per horsepower per year, the price at present being about the same as that for steam for small powers."

Rates for motor power began to come down as its use spread. In 1887, charges for motors in Boston were on a monthly basis, of which the following were typical:

Size of motor	*Rent of Motor*	*Cost of Power*	*Total cost per Year*
⅛	$0.50	$3.00	$42.00
½	1.00	5.00	72.00
1	1.00	8.00	108.00
4	5.00	26.00	372.00

In Kansas City charges were slightly higher, with a rate of $96 per year for a motor of ½ hp.; $150 for 1 hp.; and $360 for a 3 hp. motor.

Progress Slow at First

For two decades the motor business progressed but slowly. Motors were small and their use was confined to few applications, mainly elevators, printing presses, sewing machines, fans, organ blowing, lathes, coffee grinding, etc. As late as 1899 a study showed that the average electric motor was about 5 horsepower. Lathe motors ran as high as 8½ hp.; the usual elevator motor was 7 hp.; for printing, about 6 hp.; and sewing machine motors averaged 4 hp.

The year 1893 saw the historic installation by General Electric Company of a dozen or so "huge" 65-horsepower alternating current motors in the textile mills at Columbia, S. C. In 1907, motors of 6500 horsepower were being installed in the Gary Steel Mills at Gary, Ind.

In the report of 1897 of the Commissioner of Labor it is shown that of the 932 central stations, 266 were supplying electric power for motors as well as for lights, and 686 supplied light only. Of the 632 privately owned central stations, 244 rendered service to both light and motors, while 388 stations supplied current for light only. Of the 320 municipal plants, 22 supplied both light and motor service, and 298 supplied light only.

Although the total power in the manufacturing industries in the year 1899 amounted to 13,488,000 horsepower, only 182,000 hp of this was for motors run on energy purchased from central stations, or 2 per cent of the total. By 1909 the percentage had jumped to 9 per cent; in 1919 to 32 per cent; and today the percentage is 58 per cent.

Study of the Association rate books of 1903 and 1904 indicates that the central stations were trying out various methods of charging for motor power, but that most of the stations in the large cities had rates based on hours use, with sliding scales. Maximum rates began at between 10 and 15 cents per kilowatt-hour, and graduated down to various minimum amounts, some as low as 2 cents. Electric railway power was being quoted at 2 to 3 cents per kilowatt-hour.

The Bill that Failed to Pass

In the 1889 legislature of Virginia a bill was introduced—which, if adopted there and elsewhere, would have completely stifled the development of high tension alternating current transmission. The bill provided:

"The electric pressure shall not exceed the following amounts: The non-pulsating continuous current to a pressure not exceeding 800 volts; the pulsating continuous current to a pressure not exceeding 550 volts; the alternating current to a pressure not exceeding 200 volts, according to the nature of the current used."

Hearings were held on the bill by the Senate Committee to consider the bill, and distinguished witnesses appeared—including Thomas Edison, who appeared on behalf of the passage of the bill. Westinghouse retained President Morton of Stevens Institute of Technology. Edison had said in effect that the continuous current was like a river flowing peacefully to the sea, while he compared the alternating current to a torrent rushing violently over a precipice. Dr. Morton suggested that it would be more accurate to compare the continuous current to water flowing in one direction through a pipe, and the alternating current to water moving first in one direction and then in the opposite direction in the same pipe.

Fortunately for the development of water power and the successful transmission of high tension power to the factories of this country, the Senate Committee on General Laws of Virginia recommended that the bill be not passed, and the bill was killed. Many of the companies throughout Virginia supplying arc lighting to the towns and cities were using 7000-volt potentials, and the bill would have put them out of business.

Early Troubles of the Power Engineer

From an unpublished letter of the late Alex Dow to Charles E. Neil, author of the preceding article. At the time of his death in March of this year, Mr. Dow was Chairman of the Board of The Detroit Edison Company. He had been with that company and its predecessor company from 1896.

"I broke permanently into the electric light business in January of 1888, in the City of Baltimore. The outfit that I joined ran a series circuit, approximately 10 amperes, for meters, 24 hours a day excepting Sundays. There were some arc lamps on the same day circuit. Incandescent lighting circuits were turned on at dusk and run until daylight. The big snowstorm which by Eastern people was miscalled a blizzard, did not put us entirely out of action but did make a big mess of trouble. All service was sold at flat rates—so much per horsepower per annum, or so much per lamp per month. The Edison plants elsewhere had used chemical meters. The Westinghouse Company had just produced a sort of induction meter which registered energy 'within four rows of apple trees.' The Thomson-Houston people had developed but not perfected a motor meter designed by Professor Elihu Thomson, a good one.

The Most Unreliable Item

"During my first years of service the incandescent lamps were the most unreliable item. Their life was uncertain. Most of them in Baltimore in 1888 were strung in series of five lamps, and when one went out all five went out. The Company had to keep always one man and sometimes two on duty, with bags of lamps to respond to calls of 'lights out.' One man did not like to carry those bags; and being ingenious, he got his wife to fix up the lining of his winter overcoat so he could fill the skirt of it with lamps. Whereby there was a funny happening. There was a sad tragedy on the stage in the Academy of Music. The man with the packaged overcoat was, of course, a free entrant. He went in there, looked down at the show from the rail at the back of the pit and stooping, tempted the city fireman who was on duty, according to law, in the theatre, to give him a sharp swat over that portion of his anatomy which projected during the stoop. The slow music of the tragic scene was just beginning when about twenty lamps exploded and there was almost a panic in the theatre.

"I kicked around doing wiring, learning the ways of engines, etc., until I became responsible for the engineering end of a sales district of one of the older manufacturing companies. There I chased lots of trouble. The very first thing that was wished on me was a locomotive type headlight with a 20 ampere arc, on a Mississippi raft boat, which persisted in pulling an arc so long that it presently broke the circuit and put out the light. I was badly puzzled by the symptoms. I had no volt meter and an unreliable ammeter. Finally I suspected the speed and discovered that the small generator had the name plate which belonged to another machine and was being run 50 per cent too fast.

Weather Interruptions

"About weather interruptions—All of the lines for which I was responsible either as builder or operator were substantially built with so-called weatherproof wire, which wire was insulated with a cotton braid soaked with ozocerite. Voltages were low but high enough to make trouble when the wind broke off small branches of trees in wet weather and threw these across the opposite wires of a circuit. Lightning smashed insulators occasionally and in some districts would split a pole, but the lines stood up quite creditably. The meters, however, and motors and the early transformers were easy marks for lightning. On one three-wire system I found that I lost so many meters by having their potential circuit punctured that I put a 16-turn choke on each service wire. The supply was direct current and the choke did not materially reduce the voltage but it checked any secondary surge due to lightning. At the end of all branch lines I put an old fashioned lightning arrester. Then, in 1897, I went on the war-path for lightning-proof meters and ultimately got them.

Transformers

"As to transformers.—Sometime in the eighties Professor Elihu Thomson invented the safety shield which he put between the primary and secondary winding of his transformers, connecting the shield to earth, thereby putting an end to the primary current breaking through into the secondary and getting into customers' premises. The next big improvement in transformers was filling the cases with insulating oil. These Thomson inventions very much reduced the damage by lightning to transformers and the present day transformer is immune to anything but direct stroke. When you get a direct stroke you still just go and clean up the mess. Squirrels and 'coons still short-circuit a terminal occasionally putting out lights and going to animal heaven in bad order.

"Early underground cables were far from reliable. Electrical engineers had not yet discovered the different requirements for high electrical resistance, and immunity from puncture by surges. I remember certain street lighting cables on the West side of Chicago, which gave beautiful bridge tests but which punctured everytime a generator flashed over—and the generators did so quite frequently. Every time those cables punctured each of the old style grounded-return telephones in the district went out of action; and telephones were then coming into general use.

When the Customer Rejoiced

"While I was engineering for that long ago manufacturing company I installed a 220-volt, 3-wire direct current system in a small Michigan City, in competition with an alternating current service, which had oodles of transformer trouble. The transformers were of the hedge-hog type long ago forgotten. I made my customer put plenty of earth connections on the neutral wire. I told him also that the particular machines that generated his direct current would be just about immune to injury if his wires happened to be crossed with the alternating current wires of his competitor, whereas the alternator and the transformers would be damaged by the direct current if the cross came on a rainy night. The happenings were exactly according to my prediction. My customer was just mean enough to rejoice everytime that a wind and rain storm came along and these were—and are—quite plentiful in that district."—ALEX DOW.

NATIONAL ELECTRIC LIGHT ASSOCIATION
29 WEST THIRTY-NINTH STREET, NEW YORK

1923

REPORT
OF
RURAL LINES COMMITTEE

To be presented at the 46th Convention of the National Electric Light Association, Commodore Hotel, New York City, June 4 to 8, 1923

Price: Members, 15 cents; non-members, 25 cents.
Quantity prices on application.

G5-23

CONTENTS

	Page
General	3
Appendix A	22

RURAL LINES COMMITTEE

The Rural Lines Committee has continued the work started last year. Three general meetings have been held. This year's committee has paid less attention to rates and financing of lines and has paid more attention to the use and value of electric service on the farm for it is believed that if sufficient use can be made of central station service that the rate and financing problems will automatically take care of themselves.

Agricultural engineers tell us that more power is required to operate the farms than is required to operate any other industry in the United States. If each of the 6,500,000 farms in this country requires four horses the total power required and delivered from this one source is 26,000,000 horsepower. This is about equal to the combined 1922 capacity of all steam and generating central stations of the electric public utilities in the United States. Add to this 26,000,000 horsepower the combined capacity of all internal combustion engines, wind mills, steam engines and electric motors used on the farm, and the total figure becomes very large. At the present time only a small portion of the farm power load is available to the central station industry. Twenty years ago this same thing was true about industrial plants but with the development of proper electrically driven equipment this situation rapidly changed and today every utility manager considers every manufacturing plant in his territory either a customer or a prospective customer. The Rural Lines Committee believes that the farm power situation is about ready to make radical changes comparable with those made in the industrial situation during the last twenty years. The rapidity of such change depends very largely upon the amount of intelligent study put upon the farm power problem.

The Rural Lines Committee of the Wisconsin Utilities Association presents figures in its 1923 report which show that in the State of Wisconsin approximately 9 per cent of the 190,000 farms in that state have gas or electric lights. The 9 per cent of the farms is divided as follows: Of the total farms in the state 3.7 per cent get service from central stations, 3.3 per cent get service from individual farm plants and 2 per cent of the total farms have gas service.

The United States Census for 1920 shows that there were 6,448,343 farms in the United States in that year of which 452,620 or approximately 7 per cent have either gas or electric service. Assuming that the electric and gas service supplied to farmers throughout the United States bear the same ratio to each other as in Wisconsin we will arrive at the following percentages. Service from central stations, 2.9 per cent; services from individual farm lighting plants, 2.5 per cent; service from gas plants, 1.6 per cent. While a number of farms have been connected to central station lines since 1920 it will be noticed that only a small per cent of the farms in this country have central station service available.

The Rural Lines Committee believes that where central station service is available the service is being used by the farmer for only a few of the many things for which it could be profitably used. Due to this fact and to the large investment in distribution lines necessary to serve each farm the fixed charges and fixed operating costs of the average rural distribution systems are a very large per cent of the total cost of supplying rural service. If the consumption of electricity on the farm could be materially increased it could in most cases be done with only a comparatively small increase in the fixed costs and therefore the utility would be able to sell a large amount of energy to the farmer at a very much reduced cost per kilowatt hour than where only a small amount of energy is sold.

Cooperation with Agricultural Organizations

The Rural Lines Committee believes the rural electric service problems can be satisfactorily solved by increasing the use of electrical energy on the farm. The farmer cannot be expected to use electrical energy unless he can profit thereby and likewise the central station cannot be expected to sell electric service to the farmer for less than its cost plus a fair return on the necessary investment.

The Committee appreciated that a great deal of research work and study of agricultural conditions was required before profitable increased use of electrical energy could be made by the farmer and also appreciated that no complete, accurate and satisfactory study could be made without the help of men who were familiar with farm methods and farm problems. The Committee therefore as a first step toward starting such a cooperative study met on Sept. 11, 1922, with officials of the American Farm Bureau Federation and submitted the following statement:

The demand for rural electric service has produced an acute and embarrassing situation for the electrical industry due largely to the new and undeveloped state of the use of electrical energy on the farm. To develop the use of electrical energy on the farm the following suggestions are made:

1. The problem from both angles is:
(a) How service can be supplied to the farmer and what is involved in its establishment.
(b) How service can be utilized by the farmer so that it will be profitable to him.
2. It is believed that controversy is undesirable and that by cooperative efforts between the electrical and agricultural industries the problem can be solved to the best interests of all.
3. It is proposed that a cooperative organization representing these interests be formed to study the problem and to ascertain and put in form available for the use of anyone interested, the following:
(a) The various methods by which electrical energy can be profitably utilized on the farm including research studies of equipment characteristics as well as methods.
(b) The facts regarding the lines and equipment needed to give the farmer electric service comparable in quality with that already given in the industrial field.
4. The purpose of this proposed work is to ascertain facts. No selfish propaganda of any interest or class involved shall be allowed to enter.

This program was tentatively accepted by officials of the Farm Bureau as a basis for further discussion and a number of meetings were held at later

dates and it was finally agreed that it would be necessary to get help from other agricultural organizations before a complete and satisfactory study could be made of this subject. Accordingly a meeting was arranged for and held in Chicago on March 8 and the following is a report given out by that joint committee which states what was done and what is hoped to be accomplished.

At a meeting held in Chicago, March 8, 1923, by representatives of the United States Department of Agriculture, American Farm Bureau Federation, American Society of Agricultural Engineers and the National Electric Light Association, the problem of the use of electricity in agriculture was discussed.

As a result of this conference a comprehensive study of the farm power problem was outlined. Involved in this proposed investigation will be a farm power survey covering all types of farm power generators such as horses and mules, steam engines, gas engines, windmills, electric motors, and man himself. This survey will include the collecting of data on the amount of power required for various farm operations, power requirements of various machines, and working it into such a form as to make it readily adaptable to the special problem under consideration. It was emphasized that the arriving at an economic solution of this problem required, as a first step the fundamental analysis of all existing data.

It was further unanimously agreed that a complete survey of the present state of the use of electricity on the farm is desirable, and to this end plans were laid for an investigation which will reveal the number of farms being served by isolated plants and central station service. The National Electric Light Association will be requested to find the number of farm customers being served today, miles of rural electric lines, current used, farm operations for which electricity is used, and cost of this service to the farmer. An attempt will be made to secure similar data for the isolated plant.

It was recognized that the farmers rightfully look to the United States Department of Agriculture and various agricultural experiment stations for research information on fundamental agricultural problems. In view of the importance of the farm power problem it was urged that these institutions institute investigations on the application of electricity to agriculture which will ultimately place information in the farmer's hands enabling him to make intelligent decisions regarding the application of electricity to his own problems. A complete investigation of the problems in this field will be urged. As the first step in this direction the Farm Power Committee of the United States Department of Agriculture will be requested to undertake the farm power survey and complete it as rapidly as possible. The various interests represented perfected the organization of the Committee on Electricity as Related to Agriculture with J. W. Coverdale, of the American Farm Bureau Federation, as Chairman, and G. C. Neff, Chairman of the Rural Lines Committee of the National Electric Light Association, as Secretary.

Outline of investigations to be carried on under general supervision of this committee:

1. Farm Power Survey
2. Survey of Central Station and Isolated Plant Services to farmers
3. Survey of Agricultural Uses of Electricity in Foreign Countries
4. Experimental and Research Work on the Uses of Electricity in Agriculture.

The work of this joint committee will undoubtedly be beneficial to both the utilities and the farmers. The information will be collected and analyzed through the cooperation of men familiar with both agricultural and utility problems and it is confidently believed that the cooperative efforts of these people will result in avoiding many mistakes and much duplication of work.

Cost of Rural Electric Service

One of the fundamental principles of supplying rural electric service is that the utility must receive as compensation for its service the operating cost plus a fair return on any necessary investment. Everyone who has made a study of rural line situations has found that there is a great lack of information as to the cost of operating rural electric lines. In the report of last year's committee an appeal was made to the utilities to separate the cost of operating their rural lines from other operating costs. This year's committee has made special effort to collect information on this phase of the subject and has not met with as much success as was hoped for.

In order that a clear idea can be obtained as to what the committee desires in the way of detailed operating costs we show a number of tables prepared by the Union Electric Light & Power Company, giving detailed information on six lines supplying rural service and several small farmer communities in St. Louis County, Missouri. A discussion of these tables follows:

Telegraph Road, Line No. 1, is a 2300-volt, single-phase, 60-cycle No. 6 gauge copper wire, 35 ft. chestnut pole line, supplied from a 100 kv-a transformer station tapped from a 13,200 volt transmission line. It was initially constructed in July, 1921, to supply 36 customers, a few using motors, nearly all using electric ranges for cooking; length of line was 2.73 miles. Customers assisted in financing cost of line to the extent of 40.2 per cent of the recorded cost thereof, in accordance with Company's Rules and Regulations governing extensions of its Distribution System. This line has been extended to 7.393 miles in length and now supplies 76 customers.

Bellefontaine Road, Line No. 2, is a 2300-volt, single-phase, 60-cycle, No. 6 gauge copper wire, 35 ft. chestnut pole line, an extension of an existing 2300-volt system. It was initially constructed in March, 1920, to supply 14 customers, most of whom were using electric ranges for cooking; length of line was 2.56 miles. Customers assisted in financing 27.4 per cent of the initial cost of system. This line has been extended to 2,906 miles in length and now supplies 27 customers, (including a small farmer community or hamlet).

Parker Road, Line No. 3, is a 2300-volt, single-phase, 60-cycle, No. 6 B.W.G. B.B. iron wire, 30 ft. chestnut pole line, an extension of an existing 2300-volt system. It was initially constructed in February, 1920, to supply 5 customers, all using electric ranges and some small motors; length of line was 0.90 miles. Customers assisted in financing 30.2 per cent of initial cost. This line has not been extended and still supplies but 5 (original) customers.

Manchester Road, Line No. 4, is a 2300-volt, single-phase, 60-cycle, No. 6 B.W.G. B.B. iron wire, 35 ft. chestnut pole line, an extension of an existing line, overbuilding a 25 ft. subscriber telephone pole lead. It was initially constructed in May, 1917, to supply one large range, motors, and extensive lighting and appliances; approximately a 29 kw. load; length of line was 1.57 miles. Customer assisted in financing 28.6 per cent of initial cost. This line has not since been extended, but now supplies 10 customers.

Kahis Mill Road, Line No. 5, is a 2300-volt, single-phase, 60-cycle, No. 6 Ga. copper wire, 30 ft. chestnut pole line, an extension of an existing system. It was initially constructed in April, 1917, to supply 5 customers, one of which was a large dairy farm, using small motors and lights, no ranges were supplied from this line; length of line was 1.73 miles. The company financed the entire initial cost of this extension. The line has since been extended to a length of 2.43 miles and now supplies 13 customers (at one time having had as many as 16). The dairy farm is not at present a customer, having become insolvent during 1922.

TABLE I

Rural Line Study and Data

Union Electric Light & Power Company (St. Louis County, Missouri)

Period—December 1, 1921 to November 30, 1922 (12 Months)	Line No. 1	Line No. 2	Line No. 3	Line No. 4	Line No. 5	Line No. 6	Total Lines 1 to 6
1 TOTAL INVESTMENT	*$19,579.12*	*$6,194.18*	*$1,467.89*	*$2,448.01*	*$4,203.76*	*$17,159.32*	*$51,052.28*
(a) Primary Lines	8,927.01	4,012.26	770.00	1,962.73	3,024.59	11,938.64	30,635.23
(b) Secondary Lines	3,425.84	557.28	250.64	104.99	331.36	2,682.95	7,353.06
(c) Services	1,601.47	752.11	207.35	108.94	445.75	505.04	3,620.66
(d) Step Down Transformers	2,485.99	608.03	171.73	187.63	304.16	1,505.22	5,262.76
(e) Meters	1,097.87	264.50	68.17	83.72	97.90	527.47	2,139.63
(f) Sub-station Serving	2,040.94	.....	.....	.....	.....	.....	2,040.94
2 FINANCING OF LINE-TOTAL COST	*$19,579.12*	*$6,194.18*	*$1,467.89*	*$2,448.01*	*$4,203.76*	*$17,159.32*	*$51,052.28*
(a) Amount Paid by Company	10,895.85	4,071.41	1,023.54	1,844.50	3,664.34	15,679.93	37,179.57
(b) Amount Paid by Consumers	8,683.27	2,122.77	444.35	603.51	539.42	1,479.39	13,872.71
(c) Per Cent Paid by Company	55.6	65.8	69.7	75.4	87.2	91.4	72.8
(d) Per Cent Paid by Consumers	44.4	34.2	30.3	24.6	12.8	8.6	27.2
3 TOTAL CUSTOMERS (Avg. during 12 mo.)	*54.7*	*26.16*	*5.0*	*9.58*	*13.41*	*39.25*	*148.10*
(a) Lighting & Appliances	10.4	11.58	.....	8.58	8.00	29.83	68.39
(b) Range & Light	43.2	14.58	3.0	.....	5.00	5.42	71.20
(c) Motors & Light	0.4	.....	.....	0.83	0.41	2.00	3.64
(d) Motor, Range & Light	0.7	.....	.....	0.17	.....	2.00	4.87
4 CONNECTED LOAD (K.W.)	*354.27*	*130.16*	*39.95*	*19.01*	*36.45*	*145.45*	*725.29*
(a) Lighting & Appliances	58.13	23.46	5.95	13.61	9.66	47.92	158.73
(b) Ranges	295.12	106.70	32.50	1.65	21.00	91.28	548.25
(c) Motors	1.02	.....	1.50	3.75	5.79	6.25	18.31
5 STEP DOWN TRANSFORMERS							
(a) Number	18.66	9.58	2.00	4.00	8.00	8.5	50.74
(b) K. V. A. Rating	186.87	67.5	20.00	13.00	42.33	124.16	453.86
(1) Avg. Capacity K.W. per Transformer	10.01	7.05	10.00	3.25	5.29	14.61	8.94
6 PHYSICAL CHARACTERISTICS							
(a) Length in Miles	5.24	2.77	0.9	1.57	2.43	7.44	20.35
(b) Size Conductor	6	6	6	6	6	4	6 & 4
(c) Material of Conductor	Copper	Copper	Iron	Iron	Copper	Iron	Copper & Iron
(d) Phases	1	1	1	1	1	3	1 & 3
(e) Primary Voltage	2300	2300	2300	2300	2300	13200	2300 & 13200
(f) Predominating Pole Size	35ft. by 7in. Chest	35ft. by 7in. Chest	30ft. by 7in. Chest	35ft. by 7in. Chest	35ft. by 7in. Chest	40ft. by 7in. Chest	30,35&40 Chest
(g) Kind of Poles	201.08	106.00	36.00	66.00	106.00	290.00	805.08
(h) Number of Poles	38.6	38.00	40.00	42.00	44.00	39.00	39.6
(i) Avg. Number Poles per Mile							
7 TRANSFORMER STATION FEEDING LINE							
(a) Size K. V. A	100.00	.....	.....	.....	.....	.....	100.00
(b) Cost	2,040.94	.....	.....	.....	.....	.....	2,040.94

TABLE II

RURAL LINE STUDY AND DATA

UNION ELECTRIC LIGHT & POWER CO. (ST. LOUIS COUNTY, MISSOURI)

PERIOD DEC. 1, 1921 TO NOV. 30, 1922—12 MONTHS

	For Rural Lines						
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	All Six
1 LOAD STATISTICS							
(a) Input Kwh. (Metered-Main Primary Meter)	70,450	34,130	5,030	8,390	12,320	106,470	236,790
(b) Out. Kwh. (Metered-Sum of Indiv. consumers meters)	54,476	26,116	3,752	5,194	7,395	87,378	184,311
(c) Output in per cent of input	77.4	76.6	74.6	61.9	60.01	82.1	77.8
(d) Total Loss & Unaccounted For-Kwh	*15,974*	*8,014*	*1,278*	*3,196*	*4,925*	*19,092*	*52,479*
1. Transformer core losses—Kwh. (estimated)	10,496	4,656	1,113	1,089	2,976	11,964	32,294
2. Line, Sec. Transf. copper & all other losses—Kwh	5,478	3,358	165	2,107	1,949	7,128	20,185
(e) Total losses in per cent of input	*22.6*	*23.4*	*25.4*	*38.1*	*40.0*	*17.9*	*22.2*
1. Transformer core losses	14.9	13.6	22.2	12.9	24.2	11.2	13.6
2. All other losses	7.7	9.8	3.2	25.2	15.8	6.7	8.6
(f) Maximum 15 Min. Demand (Kw.)	63.36	23.4	10.8	6.1	11.5	51.84	.....
(g) Total Connected Load (Kw.)	354.27	130.07	39.95	18.96	36.45	145.45	725.15
(h) Demand Factor—per cent	17.85	18.0	27.0	32.1	32.4	36.6	.....
(i) Average hourly input (Kwh.)	8.04	3.89	0.575	0.958	1.41	12.17	27.05
(j) Load Factor—per cent	12.68	16.6	5.32	15.7	12.26	23.50	.....
(k) Reactance Kva—hr. Input (Metered)	46,680	21,650	3,138	4,760	17,980	480	94,688
(l) Average Power Factor (as calculated)	83.3	82.1	84.8	86.9	56.4	100	92.8
2 CUSTOMER STATISTICS							
(a) Total Investment Per Consumer	*$357.94*	*$236.78*	*$293.58*	*$255.53*	*$313.48*	*$437.18*	*$345.00*
1. In Primary Line	163.20	153.38	154.00	204.88	225.55	304.16	207.19
2. In Secondary Line	62.63	21.30	50.12	10.96	24.71	68.34	49.65
3. In Service Connections	29.28	28.75	41.47	11.37	33.24	12.86	24.46
4. In Transformers	45.45	23.24	34.34	19.58	22.68	38.34	35.48
5. In Meters	20.07	10.11	13.65	8.74	7.30	13.48	14.44
6. In Primary Substation	37.31	....	....	....	....	....	13.78
(b) Company's Avg. Annual Investment per Consumer	199.19	155.63	204.71	192.54	225.61	304.17	206.86
(c) Company's Avg. Initial Present Invest. per Consumer	143.37	150.79	204.71	184.45	232.66	284.25	177.08
(d) Kwh. Input per customer per Year	1288	1305	1006	876	919	2713	1599
(e) Kwh. Sold per customer per Year	996	998	750	542	551	2226	1244
(f) Kwh. Loss per customer per Year	292	307	256	334	368	487	355
(g) No. of Customers per Mile of Line	10.44	9.44	5.56	6.10	5.52	5.28	7.28
(h) Avg. Connected Load per Customer Kw	6.48	4.97	7.99	1.98	2.75	3.68	4.87
(i) Distribution Transf. Capacity per Consumer	3.42	2.58	4.00	1.36	3.15	3.17	3.06

TABLE III

RURAL LINE STUDY AND DATA

UNION ELECTRIC LIGHT & POWER CO. (ST. LOUIS COUNTY, MISSOURI) SIX RURAL LINES

OPERATING REVENUES—OPERATING EXPENSES—NET OPERATING REVENUES

FOR 12 MONTHS PERIOD—DECEMBER, 1921 TO NOVEMBER, 1922 INCLUSIVE

	Acctg.	Line No. 1	Line No. 2	Line No. 3	Line No. 4	Line No. 5	Line No. 6	Total Lines 1 to 6
OPERATING REVENUE—TOTAL	...	*$2,839.76*	*$1,338.83*	*$192.35*	*$314.04*	*$534.09*	*$4,127.30*	*$9,345.37*
Residence Lt. & Pr., and Commercial Lt. & Pr. A. C	...	2,839.76	1,338.83	192.35	314.04	534.09	4,127.30	9,345.37
Street Lighting	...	.....	.....	.....	.....	.....	.....	.....
Misc. Earnings—Forfeited Discounts	...	.....	.....	.....	.....	.....	.....	.....
Misc. Earnings—Allowances	...	.....	.....	.....	.....	.....	.....	.....
OPERATING EXPENSES—TOTAL (Excl. Interest on Invest.)	...	*2,531.52*	*945.12*	*203.78*	*336.05*	*550.02*	*2.626.82*	*7,193.31*
COST OF POWER & SUPERINTENDENCE	...	*397.79*	*194.72*	*28.26*	*48.26*	*68.79*	*600.15*	*1,337.97*
Supt. of Electric Department	101	11.83	5.96	0.87	1.63	2.29	19.04	41.62
Power Apportioned Proportion of Cost of Power	108	385.96	188.76	27.39	46.63	66.50	581.11	1,296.35
DISTRIBUTION—TOTAL	...	*367.46*	*160.63*	*31.14*	*46.12*	*98.63*	*373.69*	*1,077.66*
Operation—Total	...	*70.19*	*100.98*	*11.42*	*10.17*	*20.95*	*30.33*	*244.04*
Inspecting, Removing & Resetting Transformers	111	4.20	2.87	.....	.....	3.19	.....	10.26
Removing & Resetting Meters	112	19.79	2.03	3.53	.....	4.20	3.52	33.07
Inspecting and Testing Meters	113	1.20	.....	3.13	.....	.....	.....	4.33
Misc. Distribution System Operating Labor	114	.....	.....	.....	1.37	.....	.....	1.37
Meter Dept. Supplies and Expenses	115	8.52	4.03	0.76	1.47	2.06	6.15	22.99
Misc. Distribution System Supplies and Expenses	116	28.17	13.62	2.62	4.96	7.03	20.66	77.06
Voltage Regulation	117	8.31	78.43	1.38	2.37	4.47	.....	94.96
Maintenance—Total	...	*297.27*	*59.65*	*19.72*	*35.96*	*77.68*	*343.36*	*833.64*
Maintenance of Overhead Distribution System	118	295.54	55.63	19.71	35.95	77.67	334.07	818.57
Maintenance of Transformers	121	.....	3.99	.....	.....	.....	9.25	13.24
Maintenance of Meters	123	1.73	.....	.....	.....	.....	.....	1.73
Maintenance of Distr. System Bldg. Fixt. & Grounds	125	.....	0.03	0.01	0.01	0.01	0.04	0.10
Shop Machinery & Tools (Res. Cr.)	126	.....	.....	.....	.....	.....	.....	.....
Shop Expenses	128	.....	.....	.....	.....	.....	.....	.....
UTILIZATION—TOTAL	...	*88.69*	*8.64*	*2.00*	.....	*4.73*	*31.78*	*135.84*
Incandescent Lamp Renewals	138	13.65	2.22	.....	.....	4.73	8.34	28.94
Misc. Utilization Supplies and Expenses	139	.....	.....	.....	.....	.....	.....	.....
Customers' Premises Expenses	140	75.04	6.42	2.00	.....	.....	23.44	106.90
Maintenance of Lamps and Equipment	142	.....	.....	.....	.....	.....	.....	.....
COMMERCIAL—TOTAL	...	*151.72*	*66.11*	*15.19*	*43.01*	*45.51*	*154.98*	*476.52*
Collection Salaries and Commissions	401	49.19	23.51	4.45	8.44	16.89	36.63	138.11
Reading Meters and Delivering Bills	402	64.08	24.34	8.02	29.98	21.11	66.48	214.01
Collection Supplies and Expenses	403	4.36	2.20	0.41	0.85	1.13	3.30	12.25
Uncollectible Accounts (Res. Cr.)	404	5.68	2.68	0.39	0.61	1.06	8.32	18.74
Promotion of Business (Res. Cr.)	405	28.41	13.38	1.92	3.13	5.32	41.25	93.41

TABLE III—*Continued*

	Acctg.	Line No. 1	Line No. 2	Line No. 3	Line No. 4	Line No. 5	Line No. 6	Total Lines 1 to 6
GENERAL—TOTAL	...	*$ 44.04*	*$ 21.03*	*$ 3.15*	*$ 5.15*	*$ 8.22*	*$ 64.89*	*$ 146.48*
Salaries of General Officers	501	5.47	2.68	0.40	0.67	1.01	8.45	18.68
Salaries of General Office Clerks	502	9.14	4.43	0.66	1.12	1.63	13.81	30.79
General Office Rent	503							
Misc. General Office Supplies and Expenses	504	1.41	0.70	0.14	0.17	0.24	2.21	4.87
Law Expenses—General (Res. Cr.)	505	14.19	6.69	0.97	1.56	2.65	20.65	46.71
Misc. General Expenses	506	2.06	0.98	0.19	0.23	0.45	3.00	6.91
Relief and Pension Assn. Expenses (Res. Cr.)	507	11.36	5.36	0.71	1.27	2.13	16.51	37.34
Public Service Commission Expenses	508							
Maintenance of General Office Equipment	509	0.39	0.18	0.07	0.12	0.10	0.26	1.12
Maintenance of General Office Bldg. Fixt. and Grounds	510	0.02	0.01	0.01	0.01	0.01	0.01	0.07
UNDISTRIBUTED—TOTAL	...	122.62	62.12	14.82	21.92	35.10	198.57	455.15
Injuries and Damages (Res. Cr.)	551	28.40	13.37	1.84	3.13	5.32	41.28	93.32
Insurance (Res. Cr.)	552	28.39	13.36	1.84	3.13	5.32	41.26	93.30
Stationery, Printing and Postage	553	1.50	0.17	0.17	0.17	0.26	2.40	5.27
Operation of Stores Dept.	554	60.66	32.76	10.63	14.89	23.25	105.77	247.96
Maintenance of Stores Dept. Equipment	555	0.10	0.08	0.05	0.04	0.07	0.30	0.64
Maintenance of Stores Dept. Bldg. Fixt. and Grounds	556	0.29	0.19	0.06	0.11	0.18	0.80	1.63
Rent of Land, Bldgs. and Other Property	562	3.28	1.59	0.23	0.45	0.70	6.78	13.03
FIXED—TOTAL (Excl. Interest on Investment)	...	*1,359.20*	*431.87*	*109.22*	*171.58*	*289.04*	*1,202.76*	*3,563.67*
Depreciation (Res. Cr.)	592	1,276.56	400.92	97.92	163.24	274.06	1,115.31	3,328.01
Contingencies (Extraordinary) (Res. Cr.)	593							
Taxes (Res. Cr.)	594	82.64	30.95	11.30	8.34	14.98	87.45	235.66
NET OPERATING REVENUES (To Pay Interest and Return on Investment)	...	308.24	393.71	11.43	22.01	16.33	1,500.48	2,152.66
PER CENT NET REVENUE TO GROSS REVENUE	...	10.86	29.40	5.94	7.00	3.06	36.28	23.01
AVERAGE INVESTMENT FOR 12 MONTHS		$19,579.12	$6,194.18	$1,467.89	$2,448.01	$4,203.76	$17,159.24	$51,052.20
PER CENT NET REVENUE TO INVESTMENT		1.575	6.35	-(0.778)	-(0.898)	-(0.389)	8.75	4.22
INTEREST ON INVESTMENT AT 8% PER ANNUM		1,566.33	495.53	117.43	195.84	336.30	1,372.74	4,084.18
GAIN OVER OPERATING EXPENSES PLUS INTEREST—IN DOLLARS		-(1,258.09)	-(101.82)	-(128.86)	217.85	-(352.63)	127.74	-(1,931.52)
GAIN OVER OPERATING EXPENSES PLUS INTEREST—IN PER CENT		6.425	-(1.650)	-(8.778)	-(8.898)	-(8.389)	0.75	-(3.780)
AVERAGE LENGTH OF POLE LINE IN MILES		5.24	2.77	0.90	1.57	2.43	7.44	20.35
GAIN OVER OPERATING EXPENSES PLUS INTEREST—$/MILE OF LINE		-(241.62)	-(36.76)	-(143.18)	-(138.76)	-(145.07)	17.17	-(94.91)
AVERAGE CUSTOMERS CONNECTED—NUMBER		54.7	26.16	5.0	9.58	13.41	39.25	148.10
GAIN OVER OPERATING EXPENSES PLUS INTEREST—$/CUSTOMER		-(23.00)	-(3.89)	-(25.77)	-(22.74)	-(26.30)	3.25	13.04

Note:—	Original Length	Present Length
Line No. 1—Single phase, 2,300 Volt, #6 weather proof Copper Conductors	3.673 Miles	7.393 Miles
Line No. 2—Single phase, 2,300 Volt, #6 weather proof Copper Conductors	2.646 "	2.906 "
Line No. 3—Single phase, 2,300 Volt, #6 bare iron conductors	0.9 "	0.9 "
Line No. 4—Single phase, 2,300 Volt, #6 bare iron conductors	1.57 "	1.57 "
Line No. 5—Single phase, 2,300 Volt, #6 weather proof copper conductors	2.43 "	2.43 "
Line No. 6—Three phase, 13,200 Volt, #4 bare iron conductors	7.44 "	7.44 "

TABLE IV

RURAL LINE STUDY

BASIS OF CHARGES TO OPERATING EXPENSES OF RURAL LINES

UNION ELECTRIC LIGHT & POWER CO., ST. LOUIS COUNTY, MO.

Title	Account No.	Basis of Charges
Superintendence of Electrical Department	101	Prorated charges per Kw-hr. input into each rural line from monthly operating statement of St. Louis County Division
Power Apportioned—Proportion of Cost of Power	108	Prorated charges per Kw-hr. input into each rural line from monthly operating statement of St. Louis County Division
Inspecting, removing and resetting meters	111	Actual charges to each rural line
Removing and resetting meters	112	Actual charges to each rural line
Inspecting and testing meters	113	Actual charges to each rural line
Miscellaneous Distribution System Operating Labor	114	Actual charges to each rural line
Meter Department Supplies and Expenses	115	Prorated charges per meter, from monthly operating statement of St. Louis County Division
Miscellaneous Dostribution System Supplies and Expenses	116	Prorated charges per customer, from monthly operating statement of St. Louis County Division
Voltage Regulation	117	Actual charges to each rural line plus prorated charge to cover regulation of feeder serving rural line
Maintenance of Overhead Distribution System	118	Actual charges to each rural line plus prorated charge to cover maintenance on feeders serving rural line
Maintenance of Transformers	121	Actual charges to each rural line
Maintenance of Meters	123	Actual charges to each rural line
Maintenance of Distribution System buildings, Fixtures and Grounds	125	Prorated charges per customer, from operating statement, St. Louis County Division
Shop machinery and Tools (Res. Cr.)	126	Prorated charges per mile of line
Shop Expenses	128	Prorated charges per mile of line
Incandescent Lamp renewals	138	Actual charges from Lamp Tickets and Lamp Wagon time
Miscellaneous Utilization Supplies and Expenses	139	Actual charges to each rural line
Customers' Premises Expense	140	Actual charges, deducting direct charges borne by customer
Maintenance of lamps and equipment	142	Actual charges to each rural line
Collection Salaries and Commissions	401	Prorated charges per customer, from monthly operating statement of St. Louis County Division, plus actual cost in specific instances
Reading Meters and Delivering Bills	402	Actual charges for meter reading plus postage and mailing clerk's time
Collection Supplies and Expenses	403	Prorated charges per customer, from monthly operating statement of St. Louis County Division
Uncollectible Accounts (Rec. Cr.)	404	0. 2% of Operating Revenue
Promotion of Business Reserve Credit	405	1.0% of Operating Revenue
Salaries of General Officers	501	Prorated charges per Kw-hr. input into each rural line, from monthly operating statement of St. Louis County Division
Salaries of General Office Clerks	502	Prorated charges per Kw-hr. input into each rural line from monthly operating statement of St. Louis County Division
General Office Rent	503	Prorated charges per Kw-hr. input into each rural line

TABLE IV (Continued)

Title	Account No.	Basis of Charge
Miscellaneous General Office Supplies and Expenses	504	Prorated charges per Kw-hr. input into each rural line from monthly operating statement of St. Louis County Division
Law Expenses—General (Res. Cr.)	505	0.5% of Operating Revenue
Miscellaneous General Expenses	506	Prorated charges per Kw-hr. input into each rural line from monthly operating statement of St. Louis County Division
Relief and Pension Association Expenses (Res. Cr.)	507	0.4% of Operating Revenue
Public Service Commission Expenses	508	Prorated charges per customer
Maintenance of General Office Equipment	509	Prorated charges per customer
Maintenance of General Office Buildings, Fixtures and Grounds	510	Prorated charges per customer
Injuries and Damages (Res. Cr.)	551	1.0% of operating revenue plus specific cases
Insurance (Res. Cr.)	552	1.0% of operating revenue
Stationery, Printing and Postage	533	Prorated charges per Kw-hr. input into each rural line from monthly operating statement of St. Louis County Division
Operation of Stores Department	554	Prorated charges per mile of line, including operating labor, rent of yards and storeroom, etc.
Maintenance of Stores Department Equipment	555	Costs of maintaining stores department cranes, derricks, etc., prorated per mile of line
Maintenance of Stores, Department Buildings, Fixtures and Grounds	556	Prorated charges per mile of line
Rent of Land, Buildings and Other Property	562	Prorated charges per kw-hr. input into each rural line, from monthly operating statement of St. Louis County Division
Depreciation (Res. Cr.)	592	Percentage charge based on life of various types of equipment
Contingencies (Extraordinary) (Res. Cr.)	593	Actual charges to each rural line
Taxes (Res. Cr.)	594	Actual assessment (40% of property value) at actual tax rate for existing property in each tax district, plus taxes on general and specific equipment serving rural line estimated on a demand basis

TABLE V

RURAL LINE STUDY AND DATA

UNION ELECTRIC LIGHT & POWER CO. (ST. LOUIS COUNTY, MISSOURI)

OPERATING REVENUES AND EXPENSES

(PERIOD DEC. 1, 1921 TO NOV. 30, 1922—12 MONTHS

	For Rural Lines						
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	All Six
OPERATING REVENUES—TOTAL	*$2,839.76*	*$1,338.83*	*$192.35*	*$314.04*	*$534.09*	*$4,127.30*	*$9,345.37*
OPERATING EXPENSES—TOTAL	*2,233.92*	*853.91*	*179.25*	*295.21*	*486.15*	*2,369.48*	*6,417.91*
COST OF POWER & SUPT.—TOTAL	*396.79*	*194.72*	*28.26*	*48.26*	*68.79*	*600.15*	*1,337.97*
Superintendence	11.83	5.96	0.87	1.63	2.29	19.04	41.62
Cost of Power	385.96	188.76	27.39	46.63	66.50	581.11	1,296.35
DISTRIBUTION—TOTAL	*367.46*	*160.63*	*31.14*	*46.13*	*98.63*	*373.69*	*1,077.68*
Operation—Total	*70.19*	*100.98*	*11.42*	*10.17*	*20.95*	*30.33*	*244.04*
Inspecting, Removing and Resetting Transformers	4.20	2.87	.....	.....	3.19	.....	10.26
Removing and Resetting Meters	19.79	2.03	3.53	.....	4.20	3.52	33.07
Inspecting and Testing Meters	1.20	.....	3.13	.....	.....	.....	4.33
Misc. Distribution System Labor	.....	.....	.....	1.37	.....	.....	1.37
Meter Dept. Supplies and Expenses	8.52	4.03	0.76	1.47	2.06	6.15	22.99
Misc. Dist. System Supplies and Expenses	28.17	13.62	2.62	4.96	7.03	20.66	77.06
Voltage Regulaton and Investigations	8.31	78.43	1.38	2.37	4.47	.....	94.96
Maintenance—Total	*297.27*	*59.65*	*19.72*	*35.96*	*77.68*	*343.36*	*833.64*
Maintenance of Overhead Distribution System	295.54	55.63	19.71	35.95	77.67	334.07	818.57
Maintenance of Transformers	.....	3.99	.....	.....	.....	9.25	13.24
Maintenance of Meters	1.73	.....	.....	.....	.....	.....	1.73
General System Maintenance	.....	0.03	0.01	0.01	0.01	0.04	0.10
UTILIZATION—TOTAL	*88.69*	*8.64*	*2.00*	*0.00*	*4.73*	*31.78*	*135.84*
Incandescent Lamp Renewals	13.65	2.22	.....	.....	4.73	8.34	28.94
Customers Premises Expenses	75.04	6.42	2.00	.....	.....	23.44	106.90
COMMERCIAL—TOTAL	*151.72*	*66.11*	*15.19*	*3.401*	*45.51*	*154.98*	*476.52*
Collection Salaries and Commissions	49.19	23.51	4.45	8.44	16.89	35.63	138.11
Reading Meters and Delivering Bills	64.08	24.34	8.02	29.98	21.11	66.48	214.01
Collection Supplies and Expenses	4.36	2.20	0.41	0.85	1.13	3.30	12.25
Uncollectible Accounts (Res. Cr.)	5.68	2.68	0.39	0.61	1.06	8.32	18.74
Promotion of Business (Res. Cr.)	28.41	13.38	1.92	3.13	5.32	41.25	93.41
GENERAL—TOTAL	*44.04*	*21.03*	*3.15*	*5.15*	*8.22*	*64.39*	*146.48*
Salaries—Executive and Clerical	14.61	7.11	1.06	1.79	2.64	22.26	49.47
Misc. General Office Supplies and Expenses	1.41	0.70	0.14	0.17	0.24	2.21	4.87
Law Expenses—General (Rec. Cr.)	14.19	6.69	0.97	1.56	2.65	20.65	46.71
Misc. General Expenses	2.06	0.98	0.19	0.23	0.45	3.00	6.91
Relief and Pension Ass'n Expenses (Res. Cr.)	11.36	5.36	0.71	1.27	2.13	16.51	37.34
Maintenance of General Office Equipment, etc	0.41	0.19	0.08	0.13	0.11	0.27	1.19

TABLE V *(continued)*

UNDISTRIBUTED—TOTAL	*122.62*	*62.12*	*14.82*	*21.92*	*35.10*	*198.57*	*455.15*
Injuries and Damages (Res. Cr.)	28.40	13.37	1.84	3.13	5.32	41.26	93.32
Insurance (Res. Cr.)	28.39	13.36	1.84	3.13	5.32	41.26	93.30
Stationery Printing and Postage	1.50	0.77	0.17	0.17	0.26	2.40	5.27
Operation of Stores Dept.	60.66	32.76	10.63	14.89	23.25	105.77	247.96
Maintenance of Stores Dept. Equipt. etc.	0.39	0.27	0.11	0.15	0.25	1.10	2.27
Rent of Land, Buildings, etc.	3.28	1.59	0.23	0.45	0.70	6.78	13.03
FIXED—TOTAL	*1,061.60*	*340.66*	*84.69*	*130.74*	*225.17*	*945.42*	*2,788.27*
Depreciation (5% per Ann. on Physical Value)	978.96	309.71	73.39	122.40	210.19	857.97	2,552.61
Taxes (Actual return for District)	82.64	30.95	11.30	8.34	14.98	87.45	235.66
NET OPERATING REVENUES—TOTAL	*605.84*	*484.92*	*13.10*	*18.33*	*47.94*	*1,757.82*	*2,927.46*
PER CENT NET REVENUE & GROSS REVENUE	21.33	36.20	6.81	5.83	8.98	42.58	31.30
AVERAGE INVESTMENT FOR PERIOD	$19,579.12	$6,194.18	$1,467.89	$2,448.01	$4,203.76	$17,159.24	$51,052.20
PER CENT NET REVENUE TO INVESTMENT	3.095	7.830	0.892	0.749	1.142	10.249	5.730
INTEREST ON COMPANIES' INVESTMENT AT 8% PER ANNUM	871.67	325.71	81.88	147.56	293.05	1,254.39	2,974.37
NET OPERATING INCOME—TOTAL	-(265.83)	159.21	-(68.78)	-(129.33)	-(245.11)	503.43	-(46.91)
PER CENT NET OPERATING INCOME TO OPERATING REVENUE	9.35	11.90	-(35.75)	-(41.38)	45.90	12.19	-(0.502)
AVERAGE LENGTH OF POLE LINE IN MILES	5.24	2.77	0.90	1.57	2.43	7.44	20.35
NET OPERATING INCOME PER MILE OF LINE—$/ANNUM	-(50.70)	57.50	-(76.40)	-(82.38)	-(100.95)	67.65	-(2.31)
AVERAGE NO. OF CUSTOMERS CONNECTED	54.70	26.16	5.00	9.58	13.41	39.25	148.10
NET OPERATING INCOME PER CUSTOMER $/ANNUM	-(4.85)	6.09	-(13.75)	-(13.50)	-(18.28)	12.82	-(0.317)

TABLE VI

RURAL LINE STUDY AND DATA

UNION ELECTRIC LIGHT & POWER CO. (ST. LOUIS COUNTY, MO.)

COMPARISON AND ANALYSIS OF OPERATING REVENUES

(COVERING PERIOD FROM DEC. 1, 1921 TO NOV. 30, 1922—12 MONTHS)

	For City of St. Louis Only	For St. Louis Co. Div. Only	For Rural Lines						
			No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	All Six
1. TOTAL REVENUE FROM OPERATION (Dollars per Annum per Kw. Demand)	Per Kw. Sta. Demand	Per Kw. Sta. Demand	Per Maximum 15 Min. Kw. Line Demand						
	$ 89.55	*$ 49.34	$ 44.82	$ 57.21	$ 17.81	$ 51.48	$ 46.44	$ 79.62	$ 51.00
	Total Energy Generated								
	Switchboard Output	Switchboard Output	Total Energy Line Input (Metered)						
2 CENTS PER KWH.	2.340	*1.092	4.031	3.934	3.824	3.743	4.335	3.876	3.955
	All Classes of Service		Total Energy Sold (Metered)						
	Sold	Sold							
3 CENTS PER KWH.	3.016	1.121	5.213	5.126	5.126	6.046	7.222	4.723	5.070
	For Residence A. C. Service Only								
	5.642	6.001							
	Per $100.00 Plant Investment	Per $100.00 Plant Investment	Per $100.00 Gross Specific Investment						
4 DOLLARS PER ANNUM PER $100.00 INVESTMENT	$ 27.56	$ 52.09	‡$ 14.50	$ 21.61	$ 13.10	$ 12.83	$ 12.70	$ 24.05	$ 18.33
			Per $100.00—Company Initial Specific Investment						
			‡$ 32.70	$ 32.88	$ 18.78	$ 17.03	$ 14.58	$ 26.32	$ 25.13
	For All Customers—All classes		For Average Customer Supplied						
5 DOLLARS PER ANNUM PER CUSTOMER	$ 74.45	$126.92	$ 51.91	$ 51.18	$ 38.47	$ 32.78	$ 39.82	$105.16	$ 62.80
	For Resident Customers only								
	$ 20.31	$ 25.27							
	Total—For All Classes of Customers		Total Specific Investment in Rural Line						
6 AVERAGE PROP. & PLT. INVESTMENT PER CUSTOMER—DOLLARS	$274.12	$212.32	‡$357.94	$236.78	$293.58	$255.53	$313.48	$437.18	$345.00
			Company's Initial Specific Investment in Rural Line						
			‡$199.19	$155.63	$204.71	$192.54	$225.61	$304.17	$251.00

NOTE:—*Low-due to large block waterpower sales at low waterpower rates.
‡Does not include any apportioned investment charges in generating station, transmission, or general distribution system applicable thereto.

TABLE VII

RURAL LINE STUDY AND DATA
UNION ELECTRIC LIGHT & POWER CO. (ST. LOUIS COUNTY, MISSOURI)
COMPARISON AND ANALYSIS OF OPERATING EXPENSES
(COVERING PERIOD FROM DEC. 1, 1921, TO NOV. 30, 1922—12 MONTHS)

	For City of St. Louis only	For St. Louis County only	For County Rural Lines						
			No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	All Six
	Per Kw. Station Demand		Per Max. K. W. (15 Min.) Line Demand						
1 TOTAL ORDINARY OPERATING EXPENSES—DOLLARS PER ANNUM	$61.93	$37.187	$39.96	$40.09	$18.87	$55.09	$47.83	$50.67	$43.10
	Total Energy Generated								
	Sw-bd. Output	Sw-bd. Output	Total Energy-Line Input—(Metered)						
2 CENTS PER KWH.	1.620	0.822	3.590	2.770	4.050	4.020	4.470	2.458	3.040
	Total Energy Sold For all Classes of Service		Total Energy Sold to Rural Customers						
3 CENTS PER KWH.	2.088	0.844	4.650	3.620	5.430	6.470	7.450	2.996	3.190
	Per $100.00 Plant Investment		Per $100.00 Gross Specific Investment						
4 DOLLARS PER ANNUM PER $100.00 INVESTMENT	$18.87	$39.20	$12.94	$15.26	$13.87	$13.74	$13.06	$15.30	$14.10
			Per $100.00 Company Initial Specific Investment						
			$23.27	$23.21	$19.91	$18.22	$15.03	$16.75	$19.38
	For All Customers—All Classes		For Rural Customers Served						
5 DOLLARS PER ANNUM	$5.172	$83.30	$46.30	$36.16	$40.75	$35.20	$41.05	$66.90	$48.50
	Based on Kwh. Sold		Based on Kwh. Sold to Rural Customers						
6 DEPRECIATION EXPEN. ONLY a CENTS PER KWH.	To all Classes of Customers		2.345	1.535	2.598	3.140	3.710	1.278	1.805
			Based on Kwh. Rural Line Input						
	0.380	0.0956	$1.813	$1.174	$1.939	$1.946	$2.224	$1.050	$14.06
	Based on Kw. Station Demand		Based on Kw. Rural Line Max. Demand (15 Min.)						
b DOLLARS PER ANNUM	$11.27	$4.33	20.35	17.12	9.03	26.74	23.84	21.54	19.92
c PER CENT PER ANNUM	Based on Prop. & Plant Investment,		Based on Gross Specific Investment in Rural Line						
	3.43	4.44	6.52	6.47	6.64	6.67	6.52	6.50	6.51
			Based on Company Initial Specific Investment in Rural Line						
			11.72	9.83	9.53	8.85	7.48	7.12	8.95
d PER CENT OF TOTAL	Based on Operating Revenue		Based on Total Operating Revenue						
	12.59	8.53	45.00	29.90	50.88	51.98	51.30	27.05	35.60
e PER CENT OF TOTAL	Based on Operating Expenses		Based on Total Operating (Ordinary) Expenses						
	18.18	11.32	50.40	42.80	48.05	48.52	49.80	42.52	46.30
NOTE:—PER CENT SET-UP ON GROSS OPERATING REVENUE TO COVER DEPR. & MAINTENANCE RESERVE	15.00	11.00							

TABLE VIII

RURAL LINE STUDY AND DATA

UNION ELECTRIC LIGHT & POWER CO. (ST. LOUIS COUNTY, MISSOURI)

COMPARISON AND ANALYSIS OF OPERATING EXPENSES

(COVERING PERIOD FROM DEC. 1, 1921, TO NOV. 30, 1922—12 MONTHS)

Note:—Unit Costs—Expressed in Dollars per Annum per Customer

		For City of St. Louis only	For St. Louis County only	For County Rural Lines						
				No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	All Six
TOTAL OPERATING EXP.		$51.72	$83.30	$46.30	$36.16	$40.75	$35.20	$41.05	$66.90	$48.50
1 POWER & SUPT. EXP.	a	20.42	56.05	7.27	7.44	5.65	5.04	5.13	15.30	9.03
% Total	b	39.50	(67.25)	(15.72)	(20.60)	(13.87)	(14.36)	(12.46)	(21.85)	(18.60)
Kw. Demand $/Annum	c	-24.30-	-24.85-	-6.28-	-8.52-	-2.62-	-7.91-	-5.98-	-11.58-	-8.02-
2 DISTRIBUTION EXP.	a	1.35	2.99	6.72	6.14	6.23	4.83	7.35	9.52	7.27
% Total	b	(2.63)	(3.60)	(14.52)	(17.00)	(15.30)	(13.72)	(17.92)	(14.22)	(15.00)
A Operation	a	0.77	1.62	1.28	3.86	2.28	1.07	1.56	0.77	1.65
% Dist.	e	(56.70)	(54.20)	(19.10)	(62.80)	(36.70)	(22.00)	(21.50)	(8.07)	22.64
B Maintenance	a	0.58	1.37	5.44	2.28	3.95	3.76	5.79	8.75	5.62
% Dist.	e	(43.30)	(45.80)	(80.90)	(37.20)	(63.30)	(78.00)	(78.50)	(91.93)	77.36
3 UTILIZATION EXP.	a	1.41	1.76	1.62	0.33	0.40	0.00	0.35	0.81	0.92
% Total	b	(2.73)	(2.14)	(3.50)	(0.91)	(0.99)	(0.00)	(0.86)	(1.21)	(1.89)
4 COMMERCIAL EXP.	a	2.59	2.76	2.77	2.53	3.04	4.58	3.39	3.95	3.22
% Total	b	(5.00)	(3.35)	(6.03)	(7.00)	(7.46)	(12.79)	(8.28)	(5.90)	(6.63)
5 GENERAL EXP.	a	3.33	3.61	0.81	0.80	0.63	0.54	0.61	1.65	0.88
% Total	b	(6.44)	(4.33)	(1.74)	(2.25)	(1.55)	(1.53)	(1.50)	(2.47)	(2.04)
% 1, 2, 3 & 4	d	(12.94)	(5.67)	(4.38)	(4.89)	(4.13)	(3.75)	(3.78)	(12.60)	(4.84)
6 UNDISTRIBUTED EXP.	a	2.72	3.50	2.25	2.37	2.96	2.29	2.62	5.05	3.08
% Total	b	(5.26)	(4.20)	(4.85)	(6.57)	(7.28)	(6.52)	(6.38)	(7.56)	(6.33)
% 1, 2, 3 & 4	d	(10.55)	(5.50)	(12.18)	(14.44)	(19.36)	(15.98)	(16.12)	(17.13)	(15.05)
7 FIXED EXP.	a	19.90	12.63	24.86	16.55	21.84	17.92	21.60	30.62	24.10
% Total	b	(38.44)	(15.13)	(53.64)	(45.67)	(53.55)	(51.08)	(52.60)	(46.79)	(49.51)
% 1, 2, 3 & 4	d	(77.40)	(19.95)	(135.00)	(100.40)	(142.80)	(124.80)	(133.00)	(103.60)	(117.80)
Kw. Demand $/Annum	c	-23.86-	-5.65-	-21.45-	-18.44-	-10.12-	-28.25-	-25.30-	-23.18-	-21.35-

St. Stanislaus, Line No. 6, is a 13200-volt, 3-phase. 60-cycle, No. 4 B.W.G. B.B. iron wire, 40 ft. chestnut pole line, originally supplied from a 4400-volt, 4-wire, 3-phase source through a step-up transformer substation, now supplied direct from a 13200-volt distributing line. It was initially constructed in August, 1916, to supply one customer, a Jesuit Seminary, using three 15 kw. electric ovens, an electric range, several motors and considerable light; approximately a 70 kw. load. The length of line was 6 miles. The company financed all but 3.96 per cent of the initial cost of the line. Taps and extensions from this line have since increased its length to 7.44 miles and the line now serves 42 customers including a small farmer community.

All cost data covering plant investment was analyzed and set forth in table I from actual book entries. Customer Load and Transformer Facts and Data on Physical Characteristics of these lines are also given in Table I.

Financing of all extensions is done in accordance with rules and regulations of the company as from time to time adopted and as approved by the public service commission of the state. It is possible in all such practices to secure refund of the entire amount of such deposits on the part of the customers supplied under certain conditions. However, the amount of actual refunds hereunder have not been checked to ascertain to what extent this has actually taken place in the specific instances hereunder consideration.

Load and customer statistics are set forth in Table II in which is shown the kw-hr. input and sales to and from each line; main primary meters, watthour, reactive kv-a. and demand meters being used to measure the electrical values of the service supply. From these are derived the losses, subdivided into transformer core losses and all others, including line, transformer copper, meter inaccuracies, leakage, etc. It will be observed that the unaccounted for varied from 18 per cent to 40 per cent of the input energy (average 22.2 per cent). The maximum kw. demand for a 15 minute period was registered and recorded. The average demand per customer being slightly less than 1 kw. (950 watts). It varied, however, as follows:

Line 1— 834 watts
Line 2— 866 watts
Line 3—2160 watts
Line 4— 610 watts
Line 5— 720 watts
Line 6—1234 watts

From which the computed demand factors show variation of from 18 per cent to 30 per cent of recorded connected leads. The average annual load factors being also low, 5⅓ to 23½ per cent. The average annual power factor calculated from the reactive kv-a. meter readings and watthour meter was as low as 56.4 per cent in case of Line 5 (due to permitting large transformer to remain connected to line when not serving customers or when only lightly loaded, after the dairy farm had discontinued using service) and 100 per cent in case of Line 6 (13200-volt, 3-phase, iron wire, on wide spacing, long line and lightly loaded for long periods each day). On the other four lines 82 per cent to 87 per cent.

The average investment per customer, it will be noted, was $237.00 on Line 2, to $437.00 on Line 6, or $345.00 per customer on all six lines. It would appear that electric light and power companies cannot afford to invest initially in such business to a greater extent than is evidenced from an analysis of city systems. Total investment per customer, in any event is not out of proportion to the revenues to be derived from such service, and surely with only adequate or suitable guarantee and continuity and provision for amortization of any excess investment.

The sales per customer, in general, were fair, varying from 532 kw-hr. to 2326 kw-hr. per annum, the average being 1244 kw-hr. It is apparent, however, that the general use of electricity on the farm must be materially increased to warrant extensive developments of such service, or to be even slightly profitable to the power companies.

The average connected load varied from 2 kw. to 8 kw. in the several cases, or 4.87 kw. for all rural customers supplied from the six lines. The capacity of step-down transformers to supply this load varied from 1⅓ kw. to 4 kw., or an average of 3 kw. per customer (perhaps, somewhat larger than was warranted, due to several facts that are explained in connection with the data as presented).

The gross operating revenue per customer averaged $58.50 per annum, but varied from $33.00 to $105.00 on the rural lines. Likewise, the operating expense averaged $48.55 per customer, or from $35.00 to $67.00 on the several lines. It will be noted that before interest and return on investment was deducted, a net loss was sustained on the business from three of the six lines, while a slight marginal profit, after interest charges were taken care of, was shown on only one of the six lines. The net revenue from the business supplied over all six lines being approximately $2,150.00, but the net income fell short by about 38 per cent of that actually necessary to take care of expenses and fixed charges (including interest on investment).

In Table III are recorded actual operating revenues and expenses for each set of customers and system supplied from the six separate lines. The revenue in all cases is from the regular rural residence lighting rate schedule, excepting in a few institutions and business places supplied which were served under the company's standard commercial light and power rural rate schedule. No street lighting or other classes of service in any way helped to contribute to the revenues. No other earnings were shown or taken into account. The expenses were all shown by account classification, being actually secured and recorded monthly for the twelve months period of this study.

The basis of charges to each line covering operative expenses of these rural lines is set forth by accounts in Table IV. We believe the method is fair and equitable and we believe the information and data were carefully and conscientiously gathered and recorded.

The Cost of Power was apportioned on the basis of line input, being the switchboard cost and does not include any transmission or "city" distribution expenses to the point of delivery. This would naturally tend to materially increase the cost as applied to rural service.

The Distribution Cost includes both operation and maintenance expenses of the rural system. It is interesting to note that for these six lines, some of which are practically new at the beginning of this study and some about six years old, or less than half of their expected life spent, the average cost per mile of line was about $53.00 per annum, about 80 per cent of this cost being for maintenance alone. The figures for each line being as follows:

Line 1—$70.12 per Mile per Annum
Line 2—$58.00 per Mile per Annum
Line 3—$34.60 per Mile per Annum
Line 4—$29.38 per Mile per Annum
Line 5—$40.59 per Mile per Annum
Line 6—$50.23 per Mile per Annum
Average—$52.96 per Mile per Annum

It is to be expected that as the systems become older the expense will increase, also the climatic and other local conditions will effect these costs. It was stated that in some localities the maintenance costs were found to average about $100.00 per mile per annum.

The Utilization Expenses are a reflection of the company's policies and can be made larger or smaller either because of the extent of requirements of customers, or by changes in company's policy. They amount to only 92 cents per customer supplied from these six lines per annum; $1.76 per customer on one line to nothing on another. Certain customers' premises expenses are paid directly by the individual customer, no record having been kept of such items in this study.

The commercial expenses include collection expenses, meter reading and bill delivery, etc., and promotion of business. This cost averaged $3.22 per customer per year, or about 27 cents per month for each customer. It is dependent upon remoteness or proximity of the district served as regards working headquarters, the sparseness or density of customers, etc.

The General Expenses cover clerical and executive salaries prorated evenly against the rural service, supplies, law expenses and certain general reserve accounts. They average but 88 cents per customer per year, or about 7 cents per month.

Undistributed Expenses include certain reserve accounts to cover injuries and damages, and insurance, station printing and postage apportioned, stores expenses and rentals. They amount to $3.08 per customer per year, or about 25 cents per month.

Fixed Expenses cover depreciation on the special investment to serve the rural customers and taxes. The depreciation rate was set up on each case from a study of life tables for the items of plant involved. It develops an average life of about 15 years and was used on a straight line basis. The taxes are based on actual returns for property taxes only. Neither item includes prorated share of general plant needed to supply service and properly applicable to the rural systems. Such allocated charges should properly be reflected therein. It will be seen that the fixed expenses were about 50 per cent of the total expense recorded, averaging $24.10 per customer per annum, or a little over $2.00 per month.

Other items set forth on this table show net operating revenues and per cent net to gross revenues, per cent net revenue to investment, net operating income (after interest charges are deducted), per cent net income to revenue, net income per mile of line and per customer supplied.

This latter data was reconstructed in Table V by reducing the rate of depreciation to 5 per cent per annum on the special investment and deducting interest charges at the rate of 8 per cent per annum for that portion of investment only originally paid for directly by the company. With these modifications, the business still showed a loss. It must be remembered, however, that the company refunds to customers the money advanced to construct systems and, accordingly, eventually holds full investment in the system.

In Table VI a comparison of the operating revenues for each of the six rural lines and for all combined is made with the operating revenue from all customers supplied by the company in the city of St. Louis only and in St. Louis county only (including thirteen municipalities and much suburban territory adjacent to St. Louis), also with residence customers only in St. Louis and St. Louis county; these are analyzed on the following basis:

(1) Revenue in Dollars per Annum per kw. demand (station and line).
(2) Revenue in cents per kw.hr. generated and line input.
(3) Revenue in cents per kw.hr. sold (separately for residence service only).
(4) Revenue in dollars per annum per $100 plant investment.
(5) Revenue in dollars per annum per customer supplied.
(6) A comparison is also shown of the average property and plant investment in—
    (a) The city of St. Louis system
    (b) The St. Louis county system
    (c) Each of the rural extensions
        (1) Total specific only
        (2) That part paid for by the company initially.

It is pointed out that the revenue per kw. demand is low for the rural service, relatively, because in city of St. Louis demand is station demand. Rural line demands should be corrected for diversity, while in St. Louis county the revenue is low per kw. station demand as compared with the city of St. Louis, because of the large proportion of hydro-electric service supplied under long term contracts at lower rates (Mississippi River-Keokuk, Iowa service) reflected therein. Revenue from rural service should equal approximately $100.00 per kw. demand per annum under above circumstances to be profitable.

Revenue in cents per kw.hr. generated merely reflects the character of service in the comparison, practically no power service on high load factor in rural communities.

Revenue in cents per kw.hr. sold is actually less for the rural customers than for the urban and suburban (city and county) residence customers. (Most of the rural customers are supplied under residence rate schedule).

Revenue per $100.00 investment is very much less from rural service than city or county business, indicating the need of developing the more extensive use of electricity on the farm, also reflecting the greater density of service in urban communities than can be expected in rural territory.

Revenue per customer is not unfavorably compared for the rural business with the city service. Especially is this true of the residence accounts. It merely helps to point out that rural customers must find greater economic use of our service to make it possible for central station to supply their requirements.

In Table VII a comparison of operating expenses for each of the rural extensions and the six combined, is made with operating expense of the city of St. Louis system only and of the St. Louis county system only, analyzed under the following heads:

(1) Operating expenses-total-in dollars per annum per kw. demand.
(2) Operating expenses-total-in cents per kw.hr. generated (line input).
(3) Operating expenses-total-in cents per kw.hr. sold.
(4) Operating expenses-total-in dollars per annum per $100.00 plant investment.
(5) Operating expenses-total-in dollars per annum per customer served.
(6) Depreciation expenses compared as set-up in the above for the rural service with the reserve account method based on gross operating revenues to cover maintenance and depreciation as used in company's accounting system as it applied during the same period to the city and county systems.

Of the several methods of comparison used, that based on property and plant investment perhaps best shows the equity of the amounts set-up as proper. Rural systems should properly be charged for their proportionate amount of necessary investment in the main system supplying their service. None is reflected in the depreciation expense figures. The rate of 3.4 and 4.4. per cent on city and county systems respectively are not particularly scientific in method of application. However, it will be recognized that a large part of the investment in city and county systems is made up of land (which actually is appreciating in value) buildings with long life and low rate of depreciation, machinery and equipment that tends to lower the average rate on the entire property; whereas the rural system is essentially a pole line distributing system with whose average life most of us are in a general way familiar and which can conservatively be estimated at from 15 to 20 years maximum.

The operating expense based on the kw. demand shows the rural service not to be bearing its full share of such expenses as compared with city,—steam generated 60-cycle and d.c. service, while naturally the expense in the county system is expected to be low on account of the low cost of large quantities of hydro-electric energy purchased and delivered in large blocks.

The operating expense based on energy delivered and sold does not include for rural service the proper additional charges to cover transmission expense and other main system prorated expenses.

The expense per $100.00 plant investment and per customer is considerably lower as developed in rural systems than city and county similar costs.

In Table VIII further detailed analyses of operating expenses by divisions or groups are set forth, together with direct comparison of similar group expenses for the city of St. Louis and for St. Louis county as applied to rural service.

The operating expenses are divided into seven main divisions, or groups, in accordance with company's classification of accounts, namely:

(1) Cost of power apportioned, including superintendence of electrical department.
(2) Distribution expenses subdivided into
  (a) Operation
  (b) Maintenance
(3) Utilization expenses.
(4) Commercial expenses.
(5) General expenses.
(6) Undistributed expenses.
(7) Fixed expenses.

These are shown on the following unit basis and in comparison,—

(a) Average cost in dollars per annum per customer served for a full year.
(b) Per cent of total cost that each group bears to total expenses.
(c) Cost in dollars per annum per kilowatt of demand (station and line).
(d) Per cent of undistributed or apportioned expense that the last three groups bear to the total of the first four groups (specific charges).
(e) Per cent of total of group 2 that its subdivisions (a) and (b) bear.

It is believed that this table affords a reasonably true and fair basis of comparison in the consideration of rural service costs under present existing conditions and as modified by previous discussion herein and will be of help in arriving at a more nearly correct understanding of the basic principles underlying rate making practices governing rural service charges.

Although much more thorough study and analysis of the details of all proper charges properly apportioning and allocating such charges to the respective classes of service (including rural service) is deemed necessary and essential, it was not felt by the Committee that this properly came within the scope of its present work or at this time; neither has it had the time sufficient to devote to this purpose, nor has it secured sufficiently extensive data to make such a study representative or of greatest application from a national or association standpoint.

The special study described in detail above is not entirely typical of average rural conditions in that this rural district is located adjacent to a very large city where the cost of energy produced is extremely low. The number of customers per mile is also in excess of the number of customers usually found in rural districts, nevertheless it will be noted from this study that these six lines are not returning to the company sufficient revenue to meet the operating costs plus a fair return on the investment. The committee feels that it will be to the financial advantage of every company to make a detailed study of the cost of operating its rural lines. It will also be of material assistance to the committee in drawing definite conclusions to have a number of such surveys and detailed cost studies made.

Value of Service to the Farmer

Another fundamental principle essential to satisfactory rural electric service development is that the farmer must use the electric service at a profit to himself. The committee has therefore devoted considerable time in studying the value of this service to the farmer. In studying this subject committee members met and conferred with the following organizations and individuals: The rural lines committees of the various states, The National Farm Bureau, and the American Association of Agricultural Engineers.

The editors, managers, agricultural engineers and owners of farm publications.

The Experimental stations in several states.

The manufacturers of agricultural machinery.

The value of service to the farmer falls under three heads that come up for immediate study and one that is suggested for future investigation.

1. The value of applications already in common use.
2. The value of applications that are available but not generally used or appreciated by the farmer.
3. The value of new and proposed uses that while little understood, show enough promise to warrant immediate study of their value.
4. Many suggestions have come to the committee that seem impractical but undoubtedly many new uses of electric service will be made by the farmer as the development of the rural lines proceeds.

1. The demand for rural service seems to have been prompted solely for light to replace the kerosene lamp and the farm lantern. Little consideration seems to have been given to the economic value of this service.

The following uses for light seem to be pretty well established and are of undoubted value:

(a) The lighting of the hen house to give longer waking hours, causes an increased egg production of from 20 per cent to 30 per cent. The original experiments were made by Cornell University and have been since verified by several other state universities.

(b) The advantages gained in the industrial field by the use of light seem to hold in the farming industry. Flood lights for feed lots seem to increase the efficiency of farm labor and to increase the length of time that stock will spend at the feed box.

(c) The general efficiency of farm labor is much improved by an adequate lighting system.

(d) Electric lighted rural homes seem to be able to secure the choicest of farm labor.

(e) All of the advantages that go with properly lighted homes in the city are enjoyed in properly lighted rural homes.

The power applications that have been thoroughly proven by actual use on the farm are highly prized and are of great economic value. The only reason that they are not more generally in use, is that the proper education and selling work has not been done by the utilities.

Nothing is as valuable on the farm in proportion to its cost as an adequate water supply, yet few farmers realize it nor have the makers of electric

pumps or the sellers of power called their attention to it. Many examples can be given where the value of a good water supply has been estimated in dollars and cents that leave no question as to its value.

(a) An artesian well in the northwest costs many hundred of dollars sometimes thousands and is considered worth its cost.

(b) A Michigan banker considered a flowing well that was a little better than a small spring at more than $1.000.00.

(c) Farms with springs and running streams sell for prices much above farms that are not so equipped, even open ponds are considered valuable.

(d) One of the best examples of the value of good water supply that has come to the notice of the committee was given by an Iowa banker. On October 11, 1922, there were 58 carloads of cattle sold on the Chicago market from an Iowa station, seven carloads were from three farms equipped with automatic electric pumps and one farm that had a very valuable spring. These seven carloads sold for 21¢ per hundred pounds more than the best carload of the remaining fifty-one cars and showed more than fifty pounds per steer gain in the 128 days feeding period than the average of the fifty-one cars. While the men who were progressive enough to equip themselves with electric light and power were probably the more progressive men of the community, much of this gain was due to the better water and feed conditions.

(e) A pure water supply is fully appreciated by the dairy industry.

(f) The value of water in the home for household uses and sanitation is understood and appreciated by all city homes but little has been done to educate rural communities. Almost without exception the rural home that is equipped with an automatic water supply will admit that water for the house alone is worth the total cost of the electric power on the farm.

(g) The electric range is no longer an experiment and seems to be particularly suited for rural use.

(h) The washing machine and the utility motor, the vacuum cleaner, power sewing machine, and such utility devices are taken at their full value where used, but the proportion of rural power users that have any knowledge of any of them is small.

(i) There is little doubt that the home refrigerator will have a large field in rural districts. The committee is of the opinion that refrigerator manufacturers should develop a refrigerator suitable for farm use and that as soon as the machine is perfected the power companies should assist marketing it.

2. There are three things that have hampered the development of farm stationary power.

(a) At present there is very little farm machinery made that has been primarily designed to be used with the electric motor.

(b) The farmer on account of being pressed for time and because of the character of his equipment, has had to devote almost his exclusive attention to any machine that happened to be in use. This has resulted in machines that would do the job in a minimum of time. This condition has caused many things to be done by man or animal power that should be done by machinery. The character of farm machinery has in many cases produced results that have failed to show the full value of farm power. Farm feed grinding is a good example of this. At present the machines are large with heavy friction losses and many of them produce a grade of product that has little increased feeding value. The machine is usually designed for large capacity and must be watched constantly. One agricultural engineer has given as his opinion that the farm feed mill especially designed to operate automatically and to take not to exceed ½ to 1 horsepower would be more suited to the farmers labor conditions and give a much better product.

The investigations of the committee seem to indicate that properly ground and mixed feed has a great value to the farmer.

One large producer of ground and mixed feeds gave as his opinion that both the farmer and the producers of prepared stock food would greatly benefit by the use of the farm grinder. This company said that the greatest handicap in the sale of concentrates was that feeding without ground feed failed to derive the full benefits of the feed.

(c) While much work has been done by the experimental stations in running tests, the machinery for getting this information to the farmer has not been set in motion. The committee believes that much data of value is already available and that it need only to be collected and applied. For example, Illinois, Iowa and Minnesota experimental stations have made a very complete study of the cost of animal power. Nearly every station in the country has made many feeding tests on different kinds of feed both prepared and unprepared.

3. There are many uses for power that seem to show great promise that are little understood by either the utilities or the farmers which should be studied.

The milking machine is practical and is well understood but there is much prejudice against it.

The farm elevator use is simply a question of proper design of equipment and proper education and salesmanship.

Experiments in this country show that proper ventilation and air circulation is of immense value in the handling of damp and immature grain and that possibly forced ventilation will save the handling of much grain and in many instances save the grain itself. In England use of power in the curing of hay has shown that a better product can be secured than is at present being secured in localities where climatic conditions are good.

The Committee is of the opinion that an exhaustive study should be made by our experimental stations to determine the value of the air blower on the farm, and that its use will greatly benefit the farmer. Its use seems to appeal especially to the alfalfa grower.

The silo cutter as it is at present designed and

used is not particularly fitted for electric drive. Engineers are of the opinion that a redesign of the machinery will overcome all objections.

The farm repair shop is particularly adopted to the use of the electric motor. Agricultural engineers express themselves as being of the opinion that the motor drive repair shop will solve many of their troubles, at present there are few shops of any kind on the farm.

4. The inquiries of the committee have brought to light many subjects that should be investigated and is of the opinion that many new uses will be suggested and developed.

(a) Field power is used abroad but has not been used much in this country. There seems to be quite a good deal of experimental work being done by manufacturers that would indicate a development along this line in the near future.

(b) The electric truck for farm use and short hauls would seem to be worthy of consideration.

(c) Some experiments show that electricity is of value in fertilization of fields and that it can be used in sterilization to stop bacterial action in silos.

Development of Farm Equipment Suitable for Electric Drive

In studying the value of electric service to the farmer the committee became convinced that the service could be made much more valuable if proper electrical driven farm equipment was developed. Some time therefore was spent in collection information to determine what had been done in developing farm machines and appliances which were operated with electricity. The study was made with three objects in view:

(a) To secure information relative to the application of electricity to farm apparatus.

(b) To secure information from Agricultural Colleges and other research agencies as to cost of operation of electrically driven devices for farm use.

(c) To gather and list information so that as near a complete list of uses for electricity on the farm as possible may be available for immediate reference.

A rather voluminous correspondence was carried on with all the manufacturers of farm apparatus whose names could be secured, asking for descriptive catalogues of apparatus manufactured and for information relative to power required to drive such apparatus and for such data as the manufacturers might have, giving cost per unit produced. Similar requests were sent to a number of agricultural colleges. Publications were secured from several of the large electrical manufacturing concerns, together with transactions of societies who have had occasion to consider this subject. These publications were given careful study and consideration.

A great lack of information on the subject on the part of the manufacturers was disclosed. Apparently little is known by them regarding the application of electricity to the operation of their farm apparatus. Some conclude that as their apparatus is driven by gasoline or tractor engine power, it can be driven electrically, but as to cost of operation or definite horse power required not much information is available.

Where power requirements are given by manufacturers, they are usually stated with a variation of 100 per cent; that is, machine will require from 10 horse power to 20 horse power or from five to 10 horse power, etc.

Many expressed their interest in the matter. All expressed regrets that more information was not available. It is quite apparent that the manufacturers are not looking seriously upon electricity as a farm power agency.

Letters sent to the Agricultural Schools were not productive or much greater results. Their research along these lines apparently had not been great; not much definite information was available. All expressed interest in the work and signified an earnest desire to cooperate in any way possible. One or two stated their intention of gathering such information particularly as regards some of the most commonly used apparatus.

Publications issued by manufacturers of electrical goods give some information as to motor size required to drive farm equipment and one gives data as to cost of doing certain work. (This publication is now out of print; it appeared about ten years ago). As the art has made considerable progress since that time, these figures are not made a part of the report.

However, while the cost of operation of these various applications may not be specifically known and the manufacturers of farm equipment have not recognized to a great extent the possibility of electric drive for their machines, the Committee finds it to be a fact that there are many practical applications of electricity to the farm but before electricity can be fully and economically applied as a prime mover on the farm, it is felt that it will be necessary for the farm machinery manufacturer to redesign his product; so that the power demands will be materially reduced and the machines be made more efficient in operation.

Below is a partial list of the practical uses of electricity on the farm as gathered from manufacturer's publications, trade journals, engineering society transactions, etc.

ELECTRICITY AS APPLIED TO FARM MACHINES

Lighting
Feed grinders (small)
Feed grinders (large)
Ensilage cutters
Shredders and huskers
Threshers, 19 in. cylinder
Threshers, 32 in. cylinder
Corn shellers, single hole
Power shellers
Fanning mills
Grain elevators
Concrete mixers
Water pumps
Cream separators
Butter churns
Butter workers

Vacuum system
Refrigeration
Lathes
Emery wheels
Pasteurizers
Ice breakers.
Blower for Hay or Alfalfa drying
Groomers (vacuum system)
Hay hoists
Root cutters
Cord wood saws
Wood splitters
Hay balers
Oat crushers
Egg tester
Cider mills
Clover cutters
Lighting of chicken coops for greater egg production
Incubators
Brooders
Milking machines
Bottle washers
Bone grinders
Grindstones
Curd grinders
Forge blowers

ELECTRICITY AS APPLIED TO HOUSEHOLD MACHINES

Sewing machines
Buffers and grinders
Portable vacuum cleaners
Large ice cream freezers
Washing machines
Centrifugal dryers
Mangles
Meat grinders
Sausage stuffers
Water pumps
Dish washers
Ranges
Plus all city household uses

Attention is drawn to the meager amount of definite information available as to the cost of operation of motorized farm equipment and to the general lack of information on the part of the farm equipment manufacturers, as to the adaptability and application of electricity to the driving of their apparatus. It also desires to emphasize the fact that both the manufacturer and agricultural schools are keenly interested in having information compiled, that will provide a source of reference outlining the use of electricity on the farm.

Undoubtedly a demand on the part of the farmer for electrically operated equipment will bring it on the market, but such equipment in order to be really economical and efficient for the farmer must be designed to operate with small capacity motors, as most apparatus now produced requires motors of more than 5 horse power capacity.

It is generally acknowledged that electricity when used in connection with lighting of hen houses, incubators, brooders, milking machines, pumps, etc., has passed the experimental stages. It is thoroughly practical and productive of results.

Rules for Supplying Rural Electric Service

Due to the small amount of electrical energy used by the farmer and also to the demands made by the farmer for electric service it has been necessary to prepare rules in a number of states covering the supplying of this rural service. A number of these rules were shown in the 1922 report of this committee.

Since the 1922 report the only two states which have adopted rules providing for the establishment of rural service are the States of Oregon and Washington. In neither case do the rules apply to rural service only, but cover the general question of service extensions.

The Oregon rules are so framed that extensions of service lines above a small "free extension" are required to be made by the utility at its own expense when the ratio of annual revenue to investment is twenty-five per cent. This is a minimum. However, a provision for adjustment is made when the existing facilities are inadequate by the addition of new consumers in a district which will apparently allow a utility to place such a district on a revenue to investment basis of fifty per cent or two dollars of investment to one of revenue. The rules as written are obscure and difficult of interpretation in places. Aside from this it is felt that the attempt to specify a flat ratio of annual revenue or to fix a fixed "free extension" is not the logical way to attack the problem. The ratio of annual revenue to investment in line equipment that will place the service on a basis on which it can pay its own way is not a fixed figure, but variable, depending on the character of service and its utilization. Until a better knowledge of costs is obtained and rural service has reached a more stable state of development, it is felt that the consideration of each case, as is done in the Wisconsin rules or the newly adopted Washington rules, is justified. While no specific plan is available for general use this committee calls attention to the fact that the fundamental parts on which the business should be handled are well known. Whatever the plan adopted it should be based solidly on these fundamentals. Those were discussed in last year's report.

The Washington rules are newer but, in general, follow the outlines suggested in the recommendations of the committee of the Northwest Division of the National Electric Light Association and published in this committee report last year. While the method of handling, like that in the case of the Wisconsin rules, may not fit in other sections of this country they are sound in principle since they are based on the assumption that every dollar of investment is entitled to a fair return and should be given serious consideration by anyone called on to face the rural service problem. The rules, of course, apply to extensions generally and not to rural extensions exclusively.

From the small amount of work and investigation which has been done to date the Committee is of the opinion that with the development of proper electrically driven farm equipment and machinery a greater use will be made of electric service by the farmer which will result in larger profits to the farmer and to the utility which serves him. The perplexing problems of financing and rates which now exist and which will exist until increased use can

be made of electric service will disappear and automatically take care of themselves when such increased use of electric service on the farm becomes a fact. During this development period it will be necessary to treat the rural electric service as a special service and it is well to have specific rules covering the supplying of rural electric service and as a guide to these rules the Committee recommends a study of the various rules shown in last year's and this year's report. These rules, however, are of a temporary nature and can be eliminated when rural electric service has developed to a point where the revenue received bears a ratio to the investment comparable with the same ratio in urban business.

Respectfully submitted,

RURAL LINES COMMITTEE

G C NEFF, *Chairman*

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R J BEAUMONT
F H BROOKS
J W CARPENTER
J M DRABELLE
THOMAS F ENGLISH
R E FISHER
D L GASKILL
FRED D GORDON
L O GORDON
J E HILLEMEYER
EUGENE HOLCOMB
W H HORTON
R M HOWARD
S G HUNTER
ARTHUR HUNTINGTON
O A JENNINGS
E J JONES
W G KELLEY
R J LONG
CARL LUSCOMB
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J C MARTIN
C K NICHOLS
PHIL H PALMER
H M PARSONS
D W SNYDER, JR.
W K VANDERPOEL
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APPENDIX A

INCOMES, EXPENSES AND RETURNS FOR EXISTING RURAL EXTENSIONS

FROM RURAL LINES COMMITTEE REPORT OF WISCONSIN UTILITIES ASSOCIATION—1923

Extension No.	Revenues			Expenses					Property and Capital Investment Charges		
	Revenues from sale of electricity	Other revenues	Total revenues	Cost of energy delivered to extensions	Paid out for upkeep of lines	Taxes	Other expenses†	Total all expenses	Total cost of property	Requirement for return 8%, depreciation 4%	Amt. available for return and depreciation
1	$2,711.96	$44.62	$2,756.58	$1,482.80	$312.29	$33.62	$197.29	$2,026.00	$25,542.00	$3,065.00	$927.87
2	534.52	18.22	552.74	392.20	32.25	28.36	15.67	468.48	3,800.00	456.00	99.93
3	1,166.34	282.50	1,448.84	1,077.23	161.27	55.07	.....	1,293.57	6,970.00	836.00	155.27
4	1,004.90	12.00	1,016.90	600.94	41.95	.....	347.89	990.78	5,614.00	674.00	374.01
5	2,113.34	.....	2,113.34	734.78	78.41	17.58	113.65	944.42	missing	.....	.....
6	267.00	151.80	418.80	267.00	.....	12.12	36.85	315.97	5,200.00	624.00	139.68
7	5,019.02	199.84	5,218.86	2,085.10	33.00	14.00	2,507.35	4,639.45	39,859.33	4,783.12	3,086.76
8	368.09	.....	368.09	273.00	.....	.....	23.50	296.50	2,040.00	244.80	95.09
9	5,347.84	.....	5,347.84	3,819.85	816.98	50.91	1,074.82	5,762.56	27,198.21	3,763.77	660.10
10	587.89	.....	587.89	278.55	232.00	.....	132.26	642.81	4,525.00	543.00	77.34
11	434.57	.....	434.57	236.44	13.11	32.43	93.78	375.76	3,470.00	416.40	152.58
12	3,165.64	7.01	3,172.65	1,528.10	483.51	80.31	1,069.92	3,161.84	24,678.00	2,961.36	1,080.73
13	351.99	.....	351.99	135.60	45.00	3.46	25.00	209.06	2,300.00	276.00	167.93
14	1,391.64	200.00	1,591.64	897.40	364.00	118.58	1,100.72	2,480.70	13,554.00	1,626.48	211.66
15	211.26	41.66	252.92	151.42	13.50	21.12	10.50	196.54	3,911.60	469.39	66.88
16	2,209.72	303.50	2,513.28	882.75	987.33	265.21	431.33	2,566.62	18,295.90	2,195.51	377.99
17	430.15	38.29	468.44	360.32	39.00	.....	58.00	457.32	3,512.81	421.72	69.12
18	4,263.97	1,023.01	5,286.98	2,004.46	934.08	28.35	2,196.78	5,163.67	28,400.82	3,408.09	2,320.09
19	2,561.83	255.00	2,816.83	1,739.87	198.50	.....	645.48	2,583.85	8,600.00	1,032.00	878.46
20	483.19	.....	483.19	463.68	8.08	31.37	.....	503.13	1,767.00	212.04	(d) **19.94**
21	3,919.19	549.78	4,468.97	2,313.90	809.48	18.46	1,679.59	4,821.43	24,533.00	2,943.96	1,327.13
22	428.05	.....	428.05	206.08	48.00	.....	70.00	324.08	4,116.00	493.92	173.97
23	1,685.03	395.95	2,080.98	653.45	205.45	.....	1,228.07	2,086.97	10,436.00	1,252.32	1,222.08
24	1,255.80	.....	1,255.80	286.31	26.68	38.52	213.66	565.17	15,586.68	1,870.40	904.29
25	1,953.88	.....	1,953.88	941.40	50.15	.....	1,103.77	2,095.32	25,600.00	3,072.00	962.33
26	1,700.15	958.35	2,658.50	1,696.20	1,227.04	7.00	40.00	2,970.24	12,900.00	1,548.00	(d) **311.74**
27	2,975.26	.....	2,975.26	1,105.40	1,190.06	62.73	84.25	2,442.44	6,397.40	767.69	617.07
28	6,136.96	71.20	6,208.16	5,348.93	932.37	.....	.....	6,281.30	34,804.72	4,176.56	(d) **73.14**
29	816.08	360.00	1,176.08	844.10	28.60	5.60	187.19	1,065.49	6,954.35	834.52	297.76
30	256.21	.....	256.21	153.75	98.27	.....	.....	252.02	1,300.00	156.00	4.19
31	307.73	.....	307.73	278.36	.....	.....	.....	278.36	2,700.00	324.00	29.37
32	3,799.46	545.00	4,344.46	2,768.40	959.89	107.29	*546.78	4,382.36	12,711.18	1,525.33	(d) **37.90**

†Includes interest paid—Have assumed that other expenses consist entirely of interest, dividends paid or money spent for additions and extensions, unless the report states to contrary.

*Liability insurance and labor.

(d) Deficit.